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Primary Aluminum: Statistical Analysis of Potline Fluoride Emissions and Alternate Sampling Frequency

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Statistical analyses were performed on 4 years of fluoride emissions data from a primary aluminum reduction plant. These analyses were used to develop formulae and procedures for use by regulatory agencies in determining alternate sampling frequencies for secondary (roof monitor) emissions testing on a case-by-case basis. Monitoring procedures for ensuring compliance even with a reduced test frequency are also addressed.

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Primary Aluminum: Statistical Analysis of Potline Fluoride Emissions and Alternate Sampling Frequency

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

October 1986

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1.0 INTRODUCTION

1.1 PURPOSE

Radian Corporation provided engineering support services to the U. S. Environmental Protection Agency (EPA) Emission Standards and Engineering Division (ESED) in the evaluation of total fluoride emissions data from the Mount Holly Plant of ALUMAX of South Carolina, a primary aluminum reduction plant. Work was performed under EPA Contract Number 68-02-3816, ESED Project No. 85/11. Emissions of fluorides from the potroom groups at the ALUMAX plant are at levels well below the standard. Performance data were evaluated to establish a basis for reducing the frequency of required performance tests. The ALUMAX plant analysis may be applicable to other primary aluminum plants in the industry performing well below the standard. (See Summary of Primary Aluminum Plant Performance in Appendix D). The ALUMAX study therefore was documented in this report in a fashion that facilitates similar studies potentially to be conducted by State and local regulatory groups on other plants.

The evaluation of test data was limited to emissions from potroom groups at prebake plants. The standard for primary aluminum reduction plants (40 CFR Part 60, Subpart S) limits emissions of total fluorides (F) from potroom groups at prebake plants to 1.9 lb/ton of aluminum produced (lb F/T Al). The potroom group limit applies to the combined emission rates from the primary control device, a dry scrubber installed on the exhaust gas stream from the pots, and from the miscellaneous fugitive losses vented from the potroom enclosure through roof monitors. At ALUMAX, monthly performance tests are required on the roof monitors. The primary control devices were exempted from the monthly testing requirements consistent with the provisions of the standard [40 CFR 60.195(b)], and instead are subject to an annual performance test schedule.

If a less frequent monitoring schedule for the roof monitor emissions is to be established for a plant with performance well below the standard, some assurance must exist that the probability of exceeding the standard under the less frequent testing schedule remains at an acceptable level. In addition, quantitative criteria must be established as the basis for decisions to approve less frequent test schedules. This report addresses these concerns.

1.2 OVERVIEW OF TECHNICAL APPROACH

The following tasks were undertaken to address the concerns that a less frequent monitoring schedule pose:

- Task 1 - Analyze the ALUMAX emission data from dry scrubbers and roof monitors to characterize emissions data so that a model could be developed to predict emissions from the potroom groups and the entire plant as a function of time.
- Task 2 - Prepare control charts based on ALUMAX data 1) to establish objective criteria for measuring "performance," 2) to detect emission performance changes, and 3) to monitor operating performance in between performance tests.
- Task 3 - Using the emission-versus-time model developed in Task 1, prepare a graph of the probability of an exceedance, P(Ex), as a function of the overall mean emission rate, $\bar{X}$, and standard deviation of the mean, $S_{\bar{X}}$. The probability of an exceedance graph may be used by a regulatory authority as the quantitative basis for approving a less frequent performance test schedule, assuming that the emission performance of the potroom group, or the plant does not change.
- Task 4 - Prepare a report 1) summarizing the results of the study of the ALUMAX data and 2) outlining how a regulatory agency might qualify a primary aluminum potroom group for a reduced performance test schedule, 3) how changes in overall emission levels could be detected on a reduced performance test schedule, and 4) how the regulatory agency might be assured that the emission levels do not change between performance tests.

Tasks 1 and 3 provide the quantitative criteria for making the decision to qualify a potroom group for a reduced performance test schedule. Task 2 offers the means to detect changes in overall emission levels with the use of control charts using performance test results. The most serious problem a regulatory agency faces in granting a reduced performance test schedule is the uncertainty that exists that plant operating procedures affecting

emissions may become lax in between required performance tests. Task 4 addresses this risk by suggesting the use of a control chart which monitors plant performance continuously, whether or not the plant or potroom group is on a reduced performance test schedule.

1.3 REPORT OVERVIEW

Section 2 summarizes the overall approach to characterizing the ALUMAX emissions data and gives the results, recommendations, and conclusions of the data analysis (Task 1) and the model development (Task 3). Section 2 also summarizes the control chart parameter results and summarizes the recommendations on their use (Task 2).

Section 3 gives the details of the analysis of the ALUMAX data (Task 1).

Section 4 contains the emission model development results, and gives the procedure for constructing the Probability of Exceedance versus $\bar{X}$ and $S_{\bar{X}}$ chart (Task 3).

Section 5 outlines the theoretical basis of control chart theory and develops its application to monitoring the ALUMAX potroom groups (Task 4).

Section 6 overviews the procedure of how a primary aluminum potroom group may be qualified for reduced frequency scheduling. It then outlines how a regulatory agency may detect any overall change in emission levels, and how assurance can be given that the potroom group emissions are not changing in between performance tests.

Section 7 lists the references cited in this study.

2.0 SUMMARY

This section summarizes the data analysis approach and results of the study of fluorides emissions from the ALUMAX primary aluminum reduction plant. To aid understanding of the analysis, the production process, points of emission, and the data set are discussed briefly in the background information, Section 2.1. Section 2.2 presents an overview of the data analysis approach as well as some results and conclusions. Section 2.3 summarizes the results of the development of an emissions $\bar{X}$ versus time model. Section 2.4 discusses the Probability-of-an-Exceedance graph derived with the model and its use to qualify a potroom group for reduced frequency performance tests. Section 2.5 summarizes the concepts and results of control chart monitoring applied to a primary aluminum plant and Section 2.6 outlines regulatory procedures as they apply to reduced performance test schedules in primary aluminum plants. Section 2.7 discusses additional monitoring techniques that give the regulatory authority additional assurance that the potroom group emissions are not changing in between performance tests on a reduced test schedule. Section 2.8 briefly summarizes the development of an emissions model and regulatory procedures for a potroom group that does not fit the ALUMAX model.

2.1 BACKGROUND INFORMATION

The ALUMAX plant contains four potroom groups, as illustrated schematically in Figure 2-1. A potline is a long line of pots in which aluminum is reduced from bauxite. Aluminum reduction in an individual pot is a batch process. However, individual pots are charged on a regular, alternating schedule and the potline as a whole is presumed to be a continuous process from an emissions standpoint. The reasonableness of this presumption is more apparent when the monthly period of the sampling schedule is considered. Any model of emissions versus time is based on the presumption that the emissions from the process can be considered continuous and that periodic testing (e.g., monthly) provides a reasonable approximation of emissions during the interval between tests.

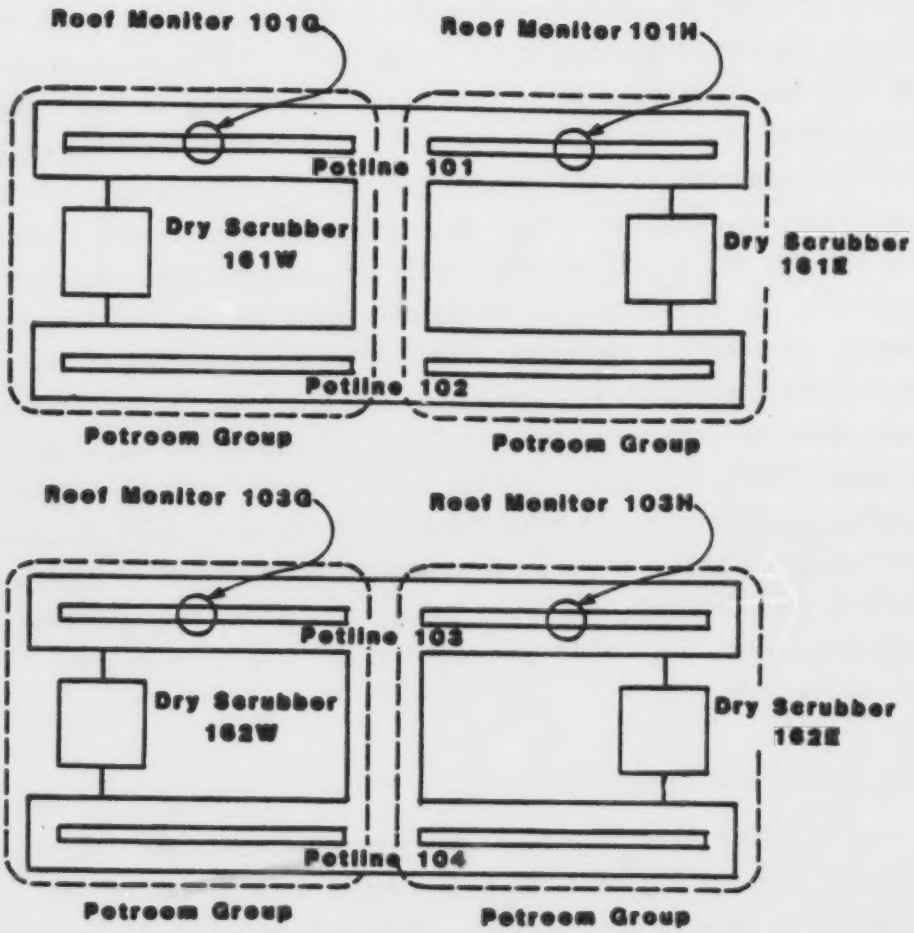


Figure 2-1. Schematic Plant Layout.

During the reduction process, the pots are enclosed and exhausted through a manifold system to a dry scrubber primary control system. Exhaust gas leaks and other fugitive emissions escape through a ventilation vent in the roof of each building referred to as a roof monitor. Emissions testing is required on the primary control device and on the roof monitors. A potroom group includes those pots vented to a common primary control device. As illustrated in Figure 2-1, the pots in a potline are segregated into two potroom groups. The concentration of pollutants exiting the roof monitor for a potroom group is determined at a single location in the roof vent. Flow or velocity is determined at several locations and averaged to calculate the total loss from the roof monitor.

Emissions data are reported by the plant for the roof monitor and primary control device for each potroom. The summation of these emission rates is compared to the 1.9 lb F/T Al standard to determine compliance. For the ALUMAX plant, data were reported for the following emission points and intervals (emission unit numbers refer to Figure 2-1):

		Consecutive Monthly Observations	Annual Observations
Potroom Group	Roof Monitor 101G	56	---
	Dry Scrubber 161W	17	2
Potroom Group	Roof Monitor 101H	56	---
	Dry Scrubber 161E	17	2
Potroom Group	Roof Monitor 103G	54	---
	Dry Scrubber 162W	15	2
Potroom Group	Roof Monitor 103H	54	---
	Dry Scrubber 162E	15	2

Both monthly and annual observations were submitted for the dry scrubbers because about a third of the way through the 4-year period for which data were submitted, the sampling frequency changed from one test per month to one test per year.

2.2 OVERVIEW OF THE DATA ANALYSIS

2.2.1 Approach

In order to develop an emissions model from the ALUMAX data, it was necessary to characterize the data and to answer certain key questions, which were:

- Should the roof monitor monthly emissions be averaged on a plantwide basis, or should the roof monitor monthly mean emissions be considered separately for each roof monitor?
- Should the dry scrubber monthly emissions be averaged on a plantwide basis, or should the dry scrubber emissions be considered separately for each dry scrubber?
- Should the potroom group monthly emissions be averaged on a plantwide basis, or should the potroom group emissions be considered separately for each potroom group?

Additional questions that remained were:

- What was the frequency distribution of the data--normal, lognormal, or another distribution?
- Was there any relationship (i.e., correlation) between roof monitor emissions and dry scrubber emissions in the same potroom group?
- Were the roof monitor monthly mean emissions data and dry scrubber emissions data autocorrelated?

The purpose of the data analysis described below was to answer all the above questions, or to provide the basis for making reasonable assumptions that would be consistent with the ALUMAX emissions data base as a whole. It was necessary to assume, for example, that the dry scrubber emissions data were not autocorrelated because there was an insufficient number of consecutive months' data to test each dry scrubber separately for autocorrelation of the monthly mean emissions. This assumption was shown to be consistent with the roof monitor monthly mean emissions data, which were not autocorrelated.

The data analysis may be outlined as follows (where appropriate, specific references to the detailed discussion sections are provided):

- Monthly means were computed and verified for each roof monitor and dry scrubber separately. (Section 3)
- Statistics were calculated for monthly means and the monthly standard deviations (of the daily performance test readings for each month) of the roof monitor emissions for all four roof monitor combined--maximum, minimum, mean, standard deviation, range, skewness and kurtosis. (Table 3-1)
- The same statistics were calculated for each roof monitor separately. (Table 3-2)
- Statistics were calculated for monthly means and the monthly standard deviations (of the daily performance test readings for each month) of the dry scrubber emissions for all four dry scrubbers combined--maximum, minimum, standard deviation, range, skewness and kurtosis. (Table 3-4)
- The same statistics were calculated for each dry scrubber separately. (Table 3-5)
- The means of the roof monitor and dry scrubbers monthly mean emissions were tested for equality between roof monitors and between dry scrubbers. (Tables A-4, A-5, and 3-3)
- A plot was made of cumulative normal probability distribution of the monthly mean roof monitor emissions and their deviation from the expected value to show graphically how well the combined roof monitor emissions data fit a normal distribution. (Figures 3-9a and 3-9b)
- A plot was made of cumulative probability of the logarithm of the monthly mean roof monitor emissions and their deviations from the expected value to show graphically how the combined dry scrubber emissions fit a lognormal distribution. (Figures 3-10a and 3-10b)

The data analysis may be outlined as follows (where appropriate, specific references to the detailed discussion sections are provided):

- Monthly means were computed and verified for each roof monitor and dry scrubber separately. (Section 3)
- Statistics were calculated for monthly means and the monthly standard deviations (of the daily performance test readings for each month) of the roof monitor emissions for all four roof monitor combined--maximum, minimum, mean, standard deviation, range, skewness and kurtosis. (Table 3-1)
- The same statistics were calculated for each roof monitor separately. (Table 3-2)
- Statistics were calculated for monthly means and the monthly standard deviations (of the daily performance test readings for each month) of the dry scrubber emissions for all four dry scrubbers combined--maximum, minimum, standard deviation, range, skewness and kurtosis. (Table 3-4)
- The same statistics were calculated for each dry scrubber separately. (Table 3-5)
- The means of the roof monitor and dry scrubbers monthly mean emissions were tested for equality between roof monitors and between dry scrubbers. (Tables A-4, A-5, and 3-3)
- A plot was made of cumulative normal probability distribution of the monthly mean roof monitor emissions and their deviation from the expected value to show graphically how well the combined roof monitor emissions data fit a normal distribution. (Figures 3-9a and 3-9b)
- A plot was made of cumulative probability of the logarithm of the monthly mean roof monitor emissions and their deviations from the expected value to show graphically how the combined dry scrubber emissions fit a lognormal distribution. (Figures 3-10a and 3-10b)

- The Kolmogorov D statistic was calculated for the combined roof monitor monthly mean emissions data and for each roof monitor separately so as to test the goodness-of-fit for the data compared to the normal and to the lognormal probability distributions. (Table 3-6)

- The autocorrelation function and the partial autocorrelation function were calculated for each roof monitor monthly mean emissions data set. These were used to characterize the autocorrelation structure of the roof monitor monthly mean emissions. (Tables A-9 through A-12)

- Covariance matrices were calculated for roof monitor and dry scrubber monthly mean emissions in the same potroom group. Correlation coefficients were calculated from each covariance matrix to determine if a correlation exists between the emissions from the roof monitor and the dry scrubber in the same potroom group. Correlation coefficients were also calculated by regressing monthly mean roof monitor data on monthly mean dry scrubber data. Plots of roof monitor monthly mean emissions versus dry scrubber monthly mean emissions gave visual interpretations of correlation. (Section 3.5)

2.2.2 Data Analysis Results and Conclusions

Overall mean roof monitor emissions, $\bar{X}$, were 0.809 lb fluoride per ton of aluminum (lb F/T Al) with a mean standard deviation of monthly means, $S_{\bar{x}}$, equal to 0.0174 lb F/T Al. The dry scrubber overall mean emissions, $\bar{X}_2$, were equal to 0.07443 lb F/T Al with a mean standard deviation, $S_{\bar{x}}$, equal to 0.050 lb F/T Al. There were sufficient differences between the overall means for each roof monitor and dry scrubber to justify treating each dry scrubber and roof monitor separately rather than using pooled values for the emissions model. The monthly mean emissions for roof monitors ranged from 0.750 to 0.870 lb F/T Al. The monthly mean emissions for dry scrubbers ranged from 0.046 to 0.101 lb F/T Al.

The graphical and statistical tests (Kolmogorov D statistics) showed that the monthly mean roof monitor emissions fit a normal distribution better than they fit a lognormal distribution. A normal distribution was therefore selected as appropriate to characterize the probability distribution of the ALUMAX monthly mean roof monitor data. The dry scrubber monthly mean emission data showed no evidence in their skewness and kurtosis values to indicate that their distribution was other than normal. It was assumed that the dry scrubber mean monthly emissions data were normally distributed.

The autocorrelation functions and partial autocorrelation functions of the roof monitor monthly mean emissions data indicated that there was insignificant autocorrelation structure. This lead to the conclusion that the roof monitor monthly mean emissions were independent (of time), random variables.

The correlation coefficients showed that there was no significant correlation between the roof monitor monthly mean emissions and the dry scrubber monthly mean emissions in the same potroom group. This result supports the assumption that the emissions variables within a potroom group were independent of one another.

Because the monthly mean emissions data for each roof monitor were found to follow a normal distribution, and because no autocorrelation behavior was found, the same model could be used for each potroom group. The facts that the monthly mean emissions from each roof monitor and each dry scrubber were significantly different from one another suggest that the monthly mean emissions should be calculated separately for each potroom group. Because insignificant correlation was found between the roof monitor and dry scrubber emissions within a potroom group, the roof monitor monthly mean emissions ($\bar{X}_1$), and the dry scrubber monthly mean emissions ($\bar{X}_2$) could be considered to be independent of one another, which affects the form of the model for the potroom group monthly mean emissions.

For the potroom groups, Section 4 postulates the total emission rate to be the sum of the roof monitor emissions and the dry scrubber emissions. The monthly variances for the potroom group are the sums of the variances of the monthly roof monitor emissions and the dry scrubber emissions. For the ALUMAX potroom groups, overall monthly means ranged from 0.8070 to 0.9618 lb F/T Al. Standard deviations ranged from 0.1340 to 0.2114 lb F/T Al.

The conclusions reached in analyzing the data were:

- The roof monitor monthly mean emissions were normally distributed, random variables;
- There were significant differences between the monthly mean emissions for the individual roof monitors;
- There were significant differences between the monthly mean emissions for the individual dry scrubbers; and
- The monthly mean roof monitor emissions and the monthly mean dry scrubber emissions in the same potroom group showed insignificant correlation.

2.3 EMISSIONS MODEL

An emissions model was developed so that it could be possible to predict for a potroom group the probability of an exceedance during normal operating conditions. The probability of an exceedance is related to measurable operating parameters, the overall monthly mean emission rate and the standard deviation of the test measurements used to calculate the monthly means. Such a Probability-of-an-Exceedance graph provides a regulatory authority with quantitative criteria for selecting which potroom group qualifies for a reduced frequent performance test schedule, and for choosing a performance test frequency.

The lack of autocorrelation of the ALUMAX roof monitor emissions data, and the determination that the data were normally distributed, simplified the preparation of the Probability-of-an-Exceedance graph. The initial design proposed for this study included the possibility that the monthly mean emissions data might have been autocorrelated. If that had been the case, the Probability-of-an-Exceedance graph would have had to be developed through computer simulations. Because the emissions were not autocorrelated, and

because the distribution followed a normal Gaussian curve, the probability of an exceedance was calculated analytically from readily available tables for the normal probability distribution.

The emissions model (developed in Section 4.0) for the ALUMAX data was that of a normally distributed random variable with a known mean and variance for each potroom group. In a potroom group, the total monthly mean emissions are the sum of the dry scrubber emissions and the roof monitor emissions; the variance of the monthly mean emissions is equal to the sum of the variances of the dry scrubber emissions and the roof monitor emissions.

The emissions model developed for the ALUMAX potroom groups is given in Equations 2-1 and 2-2.

$$\bar{X} = \bar{X}_1 + \bar{X}_2, \text{ and} \qquad (2\text{-}1)$$

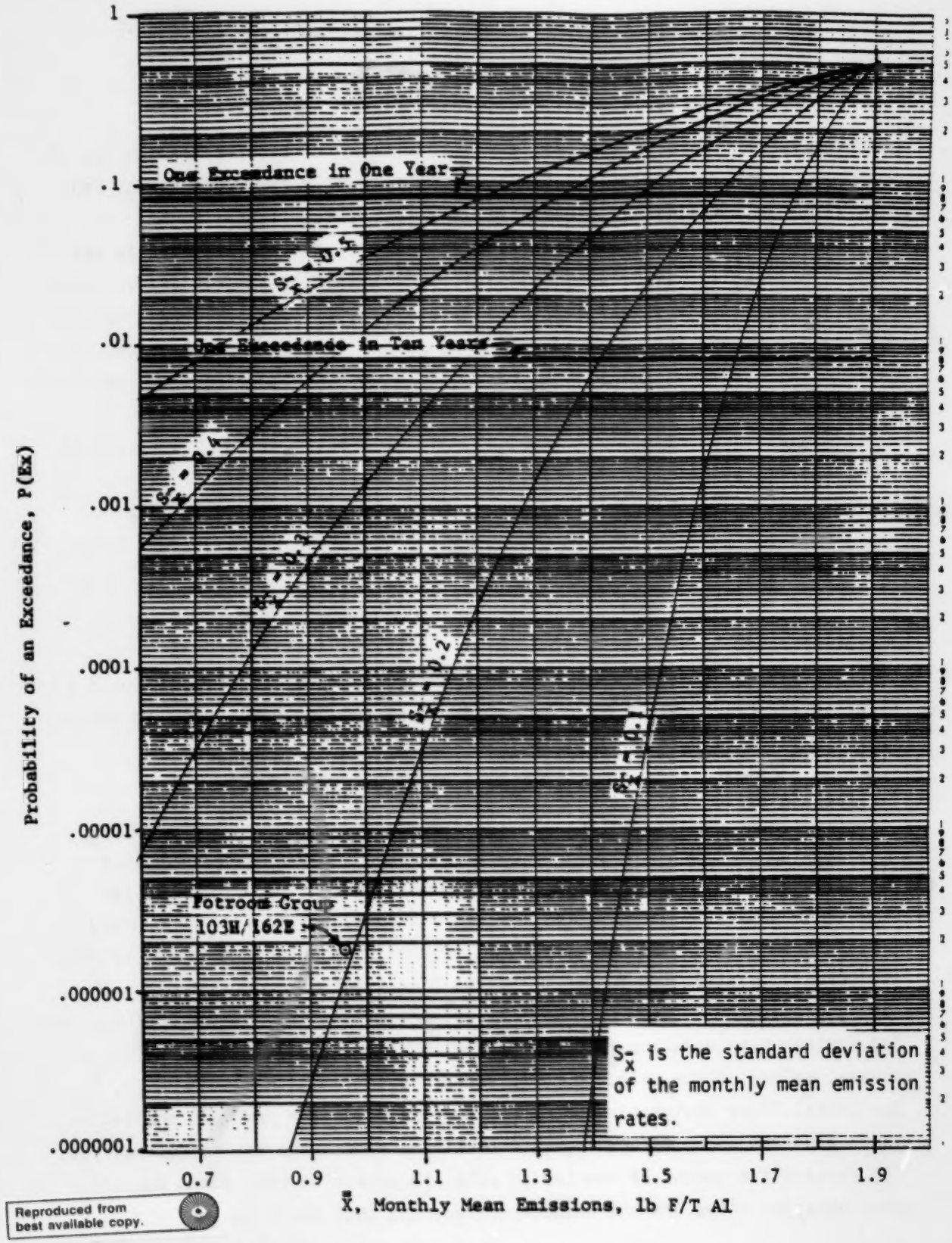
$$S^2_{\bar{x}} = S^2_{\bar{x}1} + S^2_{\bar{x}2}. \qquad (2\text{-}2)$$

Variables $\bar{X}$ and $S_{\bar{x}}$ are the monthly means and standard deviations, respectively, of emissions from the potroom groups. Variables subscripted 1, refer to the roof monitor emissions while those subscripted 2 refer to the dry scrubber emission rates.

2.4 PROBABILITY-OF-AN-EXCEEDANCE GRAPH AND ITS USE

The Probability-of-an-Exceedance graph is given in Figure 2-2. It was developed based on the emissions model and statistics (see Section 4) to provide a regulatory authority with a basis for qualifying a potroom group for a reduced frequency sampling schedule. It applies to plants whose emissions are normally distributed random variables (i.e., not autocorrelated).

The plot shows the probability of exceedance, P (Ex), on the ordinate and the monthly mean emission rate, $\bar{X}$, on the absissca. Curves are given for several values of the standard deviation of monthly mean emission rates, $S_{\bar{x}}$. Horizontal lines designating one expected exceedance per year and one in ten years also are shown on the figure. Once a potroom group has sufficient data (48 consecutive months of monitoring data) to determine that their monthly mean emission rates are not autocorrelated, and that their monthly mean



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Figure 2-2. Probability of an Exceedance.

emissions are normally distributed, it can be located on the graph by its overall monthly mean emission rate, $\bar{X}$, and standard deviation, $S_{\bar{x}}$. Its location on the Figure 2-2 determines the Probability-of-an-Exceedance for the potroom group. An example shown in the figure is that of ALUMAX potroom group 103H/162E. Its probability of exceedance is about 0.000002 or about one exceedance in over 10 thousand years. The other potroom groups at ALUMAX have a lower probability of exceedance. This information, along with a table such as that in Table 2-1 may be used by a regulatory agency to qualify a potroom group for a reduced performance test schedule.

The regulatory authority must make the selection of which regions of the graph qualify for various performance test intervals. Table 2-1 is given as an example of the criteria that may be used. ALUMAX, potroom group 103H/162E for instance would qualify for a 12-month monitoring schedule using these criteria. It must be stressed, however, that the decision about monitoring schedules are the purview of the regulating authority and must be made based on their judgment. The Probability-of-an-Exceedance graph serves only as a tool for distinguishing aluminum plant performance levels quantitatively .

TABLE 2-1. EXAMPLE CRITERIA FOR REDUCED PERFORMANCE TEST SCHEDULE

Probability of an Exceedance, P(Ex)	Example Performance Test Schedule[a]
P(Ex) > 0.001	one/month
0.0001 < P(Ex) < 0.001[b]	one/quarter
0.00001 < P(Ex) < 0.0001[c]	one/6 months
P(Ex) < 0.00001	one/12 months

[a] Selection of the performance test schedule is the purview of the regulatory authority.

[b] P = 0.001, signifies that the probability of an exceedance is 1 in 1,000 measurements on a monthly schedule, or once every 83.33 years because of random variation.

[c] P = 0.0001, signifies that the probability of an exceedance is 1 in 10,000 measurements on a monthly schedule, or once every 833.33 years because of random variation.

2.5 CONTROL CHART MONITORING

Once a potroom group has qualified for reduced performance test scheduling, the regulatory agency must be able to identify emission test results higher than the overall average caused by random variation, from those caused by changes in the overall emissions level. The control chart methods proposed in this study are well suited to make that distinction.

Control charts monitoring performance test results are based on past performance and ongoing results. Each performance test averages three daily readings of lb F/T Al for a monthly mean emission value, $\bar{X}$; a standard deviation of the three readings is also determined. Separate control charts plot $\bar{X}$ and S_x values for each performance test. For the ALUMAX potroom groups, $\bar{X}$ and S_x were found to be random variables. For each successive performance test, random variation is exhibited, but knowing the overall means, $\bar{\bar{X}}$ and $\bar{S}_x$, it is possible to set limits on the expected variations, assuming no changes occur in the overall potroom group average emissions or their variability. Control charts can identify either warning limits or control limits (or both). Warning limits are usually set at the mean value $\pm$ 2-sigma, or two standard deviations above and below the mean. Control Limits are generally set at the mean value $\pm$ 3-sigma, or the three standard deviations above and below the overall limits. Warning limits cover about 95% of the monthly means and standard deviations; control limits cover about 99% of the monthly means and standard deviations during normal random behavior of the process.

Results of periodic performance tests, whether monthly, quarterly, semi-annually, or annually, are located on their respective control chart immediately following the test. If the points fall outside the control limits of the control charts, the process, or operation is considered "out of control", and management, operating personnel, and the regulatory agency are signaled that something other than random variation is causing the emissions to be larger (or smaller) than normally expected.

Figures 2-3 and 2-4 give an $\bar{X}$-control chart and an S_x control chart respectively for ALUMAX potroom group containing Roof Monitor 101G and Dry Scrubber 161W. Shown on the charts are horizontal lines for the overall means, the central lines, and the upper and lower warning limits, UWL and LWL,

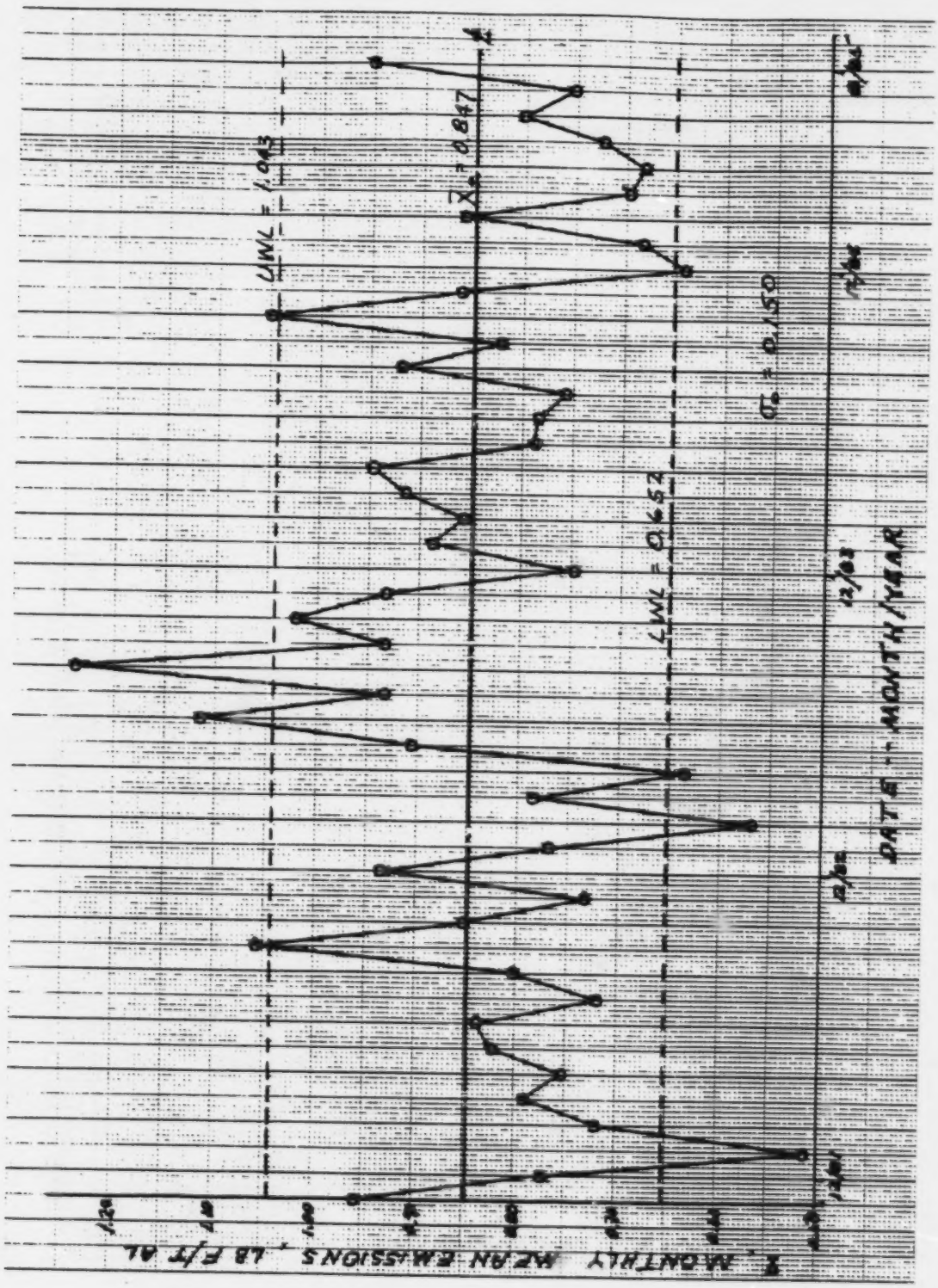


Figure 2-3. X̄ Control Chart For ALUMAX Potroom Group 101G/161W.

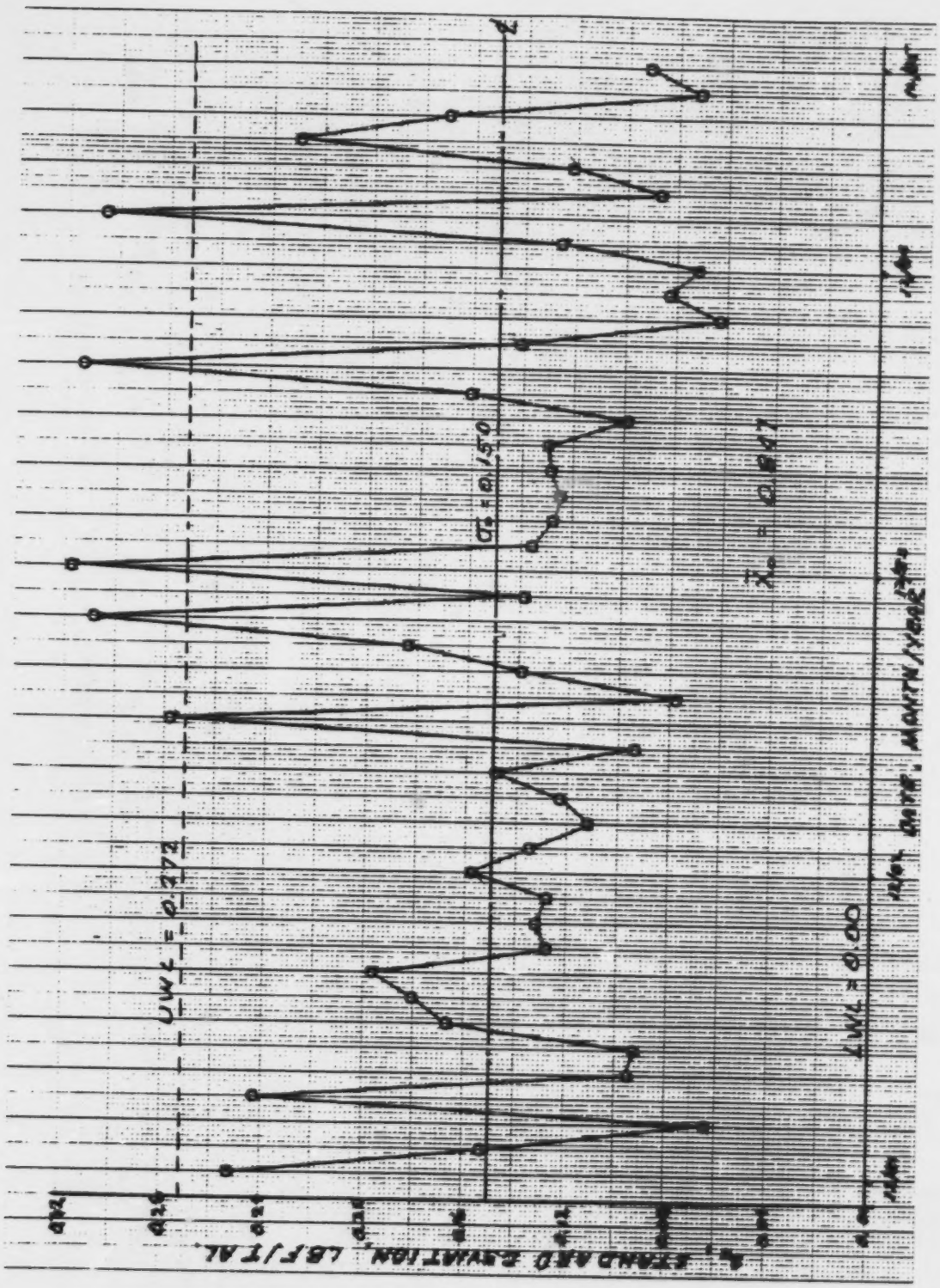


Figure 2-4. S_x Control Chart For ALUMAX Potroom Group 101G/161W.

respectively. The latter limits are set at 2-sigmas (i.e., standard deviations) above and below the central lines. The means $\pm$ 2-sigmas for a normally distributed variables should include, on the average, about 95 percent of the individual $\bar{X}$ or S_x readings. Only one datum in 20, on the average, should fall outside UWL or LWL by random variation only. If there is a change in operating procedure, or equipment failure, that affects emissions, whether increased or decreased, it will be detected on the control charts by one or more consecutive points falling outside the warning limits.

Figure 2-3 shows several monthly means above or below the warning limits--January 1982, September 1982, February 1983, April 1983, June 1983, August 1983, October 1984, and December 1984. Figure 2-2 shows five monthly standard deviations above the upper warning limit, and none below the lower warning limit. These are above the average expected number (which would be about 3 for each graph) of "violations" of UWL and LWL, but the graphs show both the $\bar{X}$ and S_x chart to recover quickly, i.e., there are not two consecutive months for which the monthly means or standard deviations are above or below UWL and LWL. The control charts demonstrate random behavior and no overall increasing or decreasing trends. The $\bar{X}$ chart (Figure 2-3) shows data from December 1981 through August 1982, nine consecutive months, below the central line. Whenever more than seven consecutive points are (1) increasing, (2) decreasing, (3) above the central line, or (4) below the central line, a "run" has occurred and the process is said to be "out of control." The system is seen to exhibit random behavior afterwards, so that the early out-of-control condition may relate to plant startup causes. Aside from the early excursion into an out-of-control condition in the $\bar{X}$ chart, both Figures 2-3 and 2-4 show a process that is "in control."

Control charts for the other potroom groups at ALUMAX could be plotted and would resemble those in Figures 2-3 and 2-4. The key parameters for establishing these charts are the mean, standard deviation, the central line, UWL, and LWL for emissions from each group. From these the warning and control limits are constructed. Table 5-5 lists these key parameters for possible use at ALUMAX.

An important feature of the use of control charts is that an out-of-control situation generally does not mean that the NSPS emission level (1.9 lb F/T Al) has been exceeded. It indicates that the emissions have

exceeded the range expected by random variation based on the past history of the plant operating procedures and emission levels. An out-of-control situation, or a situation in which the warning limits have been exceeded may require recertification by the regulatory agency for a reduced performance test schedule. Possible regulatory provisions such as this are summarized in Section 2.6 below and are fully developed in Sections 5 and 6.

2.6 REGULATORY PROCEDURES OVERVIEW

The ALUMAX model may be used for any potroom group whose monthly mean emissions are normally distributed, random variables. The latter implies that the monthly mean emissions are not autocorrelated. Initial qualification of a potroom group for a reduced performance test schedule requires a minimum of 48 consecutive months of performance testing to verify 1) that the monthly mean emissions are not autocorrelated, and 2) they fit a normal Gaussian frequency distribution. If both criteria are met, the regulatory authority may decide on a performance test schedule based on their past performance. An example set of quantitative criteria that might be used to qualify a potroom group for reduced monitoring frequency is offered in Table 2-1. The probability of an exceedance value for a potroom group may be determined in Figure 2-2 as a function of $\bar{\bar{X}}$, the overall monthly mean emissions, and $S_{\bar{X}}$, the standard deviation of the monthly mean emissions, determined from the 48 months of testing.

During the period of the reduced performance test schedule, the potroom group should maintain two control charts, $\bar{X}$ and S_X, for performance test results. Initially, the control chart parameters are based on the data gathered during the 48 months of operation needed to qualify the potroom group for reduced performance test schedule. Central lines and upper and lower warning limits are identified for each chart according to the methods described in Section 5 and Appendix B.

Whenever the performance test gives results outside the warning limits on any of the control charts, appropriate action must be taken by the plant operating personnel. The action recommended is to look for any cause in the plant that may have contributed to the result's lying outside the warning limits, and to perform an additional performance test the next month. The

purpose of these actions is for the regulatory agency (and the plant operating personnel) to be able to make a judgement as to whether the violation of the warning limit was caused by random variation or whether the overall plant operating emission level has changed. Procedures are outlined in Sections 5 and 6 for making such a judgement with a known probability (usually 95 percent probability) of making the correct judgement.

If the conclusion is reached based on a series of monthly performance tests that the overall emission level of the potroom group has either increased or decreased from the initial operating levels, the potroom group must be recertified for the appropriate performance test schedule, using the Probability-of-an-Exceedance graph Figure 2-2 and Table 2-1, and new control chart parameters derived.

2.7 ADDITIONAL MONITORING TECHNIQUES

The inherent weakness in monitoring fluoride emissions with the techniques outlined above is that the regulatory authority must assume that there is no change in operating or maintenance procedures that affect emission rates in between performance tests. If the potroom group is on an annual performance test schedule, there is a risk that the overall emission level may have changed, or even that the standard may have been exceeded for several months without detection.

To help prevent such occurrences, it is suggested that maintenance practices that reduce emissions be monitored on a daily or weekly basis. Control chart theory as described for use with emission test data, may be used with maintenance practices as well. At least one additional plant operating parameter should be monitored with control charts on a continuing basis before and after the potroom groups are given a reduced frequency performance test schedule. The additional parameter can be one or more of the normal routine operating practices that are carried out. For example, ALUMAX inspects each potline weekly to determine how many panels on each pot are damaged or improperly fitted and need replacing, or tightened in place. In addition, the vent hoods over each pot are inspected daily to verify that they are correctly in place, and they have not been left retracted too long after an anode has been replaced. Records are kept[20] each week of the number of panels and the

number of hoods that need adjustment or maintenance. The results of these panel and hood inspection reports give indications of the operating efficiency and performance of the plant operating personnel. The number of loose and ill-fitting panels and hoods also relates to fluoride emissions levels.

Past history of hood and panel inspections at ALUMAX or another plant could be used to develop $\bar{X}$ and S_x charts for each potroom with their appropriate warning or control limits. Violations of the limits on the hood and panel inspection control charts could indicate a change in normal operating and maintenance practices at the plant which could affect emissions. For regulatory purposes, such additional control charts could be required to be used weekly to monitor ongoing operating and maintenance performances. Any violation of the control limits on these surrogate monitoring parameters could trigger additional performance tests in between the regularly scheduled performance tests to verify whether or not the potroom group is still in control from the standpoint of their emissions level and its variability.

Such a regulatory requirement would give added assurance to the regulatory authority that the potroom group emissions are not changing in between regularly scheduled performance tests. The additional cost to the plant would be much smaller than the savings gained on performance test cost on a reduced frequency schedule.

2.8 EMISSION MODELS NOT FITTING ALUMAX MODEL

Recapitulating the essential features of the ALUMAX model are: 1) the potroom group mean monthly emissions are normally distributed, 2) the potroom group monthly mean emissions are random variables, and 3) the roof monitor and dry scrubber emissions are independent of one another. Should a potroom group's data not fit all of these three requirements, some adjustments to the ALUMAX model should be made, before a new potroom group should be qualified for reduced performance testing by the methods recommended in earlier sections of this report.

The simplest adjustment to make would be if the roof monitor monthly mean emissions and the dry scrubber emissions displayed covariance. This would require adding a covariance term to Equation 2-2. The equation for variance (standard deviation squared) for the potroom group would then read

$$S^2_{\bar{x}} = S^2_{\bar{x}1} + S^2_{\bar{x}2} + 2r\, S_{\bar{x}1}\, S_{\bar{x}2}, \qquad (2\text{-}3)$$

where r = the correlation coefficient of $\bar{X}_1$ and $\bar{X}_2$, and $S_{\bar{x}1}$ is the standard deviation of $\bar{X}_1$ and $S_{\bar{x}2}$ is the standard deviation of $\bar{X}_2$.

The last term in Equation 2-3 accounts for the covariance of the roof monitor and dry scrubber monthly means.

One $S_{\bar{x}}$ has been calculated for a new potroom group from Equation 2-3, it may be used with $\bar{\bar{X}}$, the overall mean, Figure 2-1, and Table 2-1, by the regulatory authority to qualify the potroom group for a reduced performance test schedule as indicated above. No adjustment of the control chart parameters is required from the control chart procedures detailed in Sections 5 and 6, and Appendix B because of the covariance of the roof monitor and dry scrubber emissions.

If the potroom group emissions are not normally distributed, then a new Probability-of-Exceedance graph is needed to replace Figure 2-2 (and 4-1). If the emissions are lognormally distributed, tabulations are available for that distribution. Other non-normal distributions may require a computer simulation in order to calculate the probabilities for $\bar{\bar{X}}$ and $S_{\bar{x}}$, so that a new Probability-of-Exceedance graph can be constructed for qualifying the potroom group.

Finally, if there is an autocorrelation structure to the data, i.e., the potroom group monthly mean emissions are not random variables, then a new Probability-of-an-Exceedance graph (Figure 2-2) will be required. Autocorrelation complicates the model to the point that the best way to calculate the probability of an exceedance for a given $\bar{\bar{X}}$ and $S_{\bar{x}}$, is through computer simulation. No change would be required in the control chart procedures outlined above or in Section 5 because of the autocorrelation structure of the data.

As a result of the analysis of the ALUMAX data, it is not thought likely, however, that monthly mean emissions from a potroom group in a primary aluminum plant would not meet the requirements needed to use the ALUMAX model developed in this study.

3.0 DATA ANALYSIS

The analysis of the ALUMAX emission data is discussed in this section. Section 3.1 examines the roof monitor data to define the overall means, standard deviations and other statistics for each roof monitor separately and for all four monitors combined. Annual monthly averages for each roof monitor are plotted to discern trends and differences between monitors. Section 3.2 examines the dry scrubber data in a similar manner, except that after April 1982 only annual performance tests were reported for 1983 and 1984. The purpose of the analysis of the dry scrubber data was to determine if there were significant differences in the operating characteristics (means, standard deviations, etc.) between dry scrubbers.

Section 3.3 addresses the question of the choice of the data distribution to be used in the model. It is necessary to determine whether the emission data are normally distributed, lognormally distributed, or follow some other frequency distribution. Because the roof monitor data account for about 90 percent of the total emissions, the frequency distribution of the roof monitor emissions will be used to develop the model. There are insufficient dry scrubber data to test adequately various frequency distributions for goodness-of-fit, therefore the dry scrubber emissions will be assumed to be normally distributed.

Section 3.4 explores the time series character of the data, looking particularly for autocorrelation behavior. Because th NSPS emission limit for potroom groups in primary aluminum plants is based on the sum of the emissions from roof monitors and dry scrubbers, the covariance of the monthly means for these emission points was investigated. The covariance of these two parameters is analyzed and reported in Section 3.5.

Finally in Section 3.6 the character of the emissions from the ALUMAX plant is summarized and a choice is made of how the data are to be treated in the proposed model.

3.1 ROOF MONITOR DATA

The data base used in this study was obtained from the Mount Holly plant of ALUMAX of South Carolina.[1,2] These data are provided in Tables A-1

and A-2 in the Appendix. The roof monitor data are shown in Figures 3-1 through 3-4 for Roof Monitors 101G, 101H, 103G, and 103H, respectively. The data appear to be similar in their average emission levels, variability, and sequential behavior.

Table 3-1 gives summary statistics for all four of the ALUMAX roof monitor data grouped together. The variable labeled "XBAR" is the monthly mean value of three daily determinations (occasionally only two daily readings were available for a specific month). Variable "SX" is the standard deviation of the two or three daily emissions for a given month. Both these emission variables carry units of pound(s) of fluoride emissions per ton of aluminum produced.

Statistics shown in Table 3-1 are the number of cases, the minimum, the maximum, the range, the mean, the standard deviation, the skewness, and the kurtosis. Positive skewness measures a frequency distribution which exhibits a "tail" to the right of the most frequent value which is longer than the tail to the left of the most frequent value. A lognormal distribution for example would have a positive skewness, usually greater than 2.0. An approximately normal distribution would have a skewness near zero. Kurtosis, or the coefficient of kurtosis, measures the peakedness of a distribution. For a normal distribution the kurtosis has a value of 3.0. If the kurtosis exceeds 3, the distribution has longer tails than a normal distribution with the same variance; if the kurtosis is less than three, the distribution is more peaked than the normal distribution with the same variance. For a lognormal distribution[9] the kurtosis is a function of the standard deviation, σ, the kurtosis ranges from 0.0 to 6.235×10^{27} as σ ranges from 0 to 4.0. A lognormal distribution having a standard deviation, equal 0.150 would have a kurtosis of 0.372; if σ equals 1.0 the kurtosis would equal 110.94.

While the skewness and kurtosis statistics are, in themselves, insufficient to test the data for normality, or lognormality, they can give such information as:

1. Does the set approximate normal (or lognormal) behavior?
2. Do two or more data samples appear to be approximately from the same population?
3. Are the data skewed to the right or to the left?

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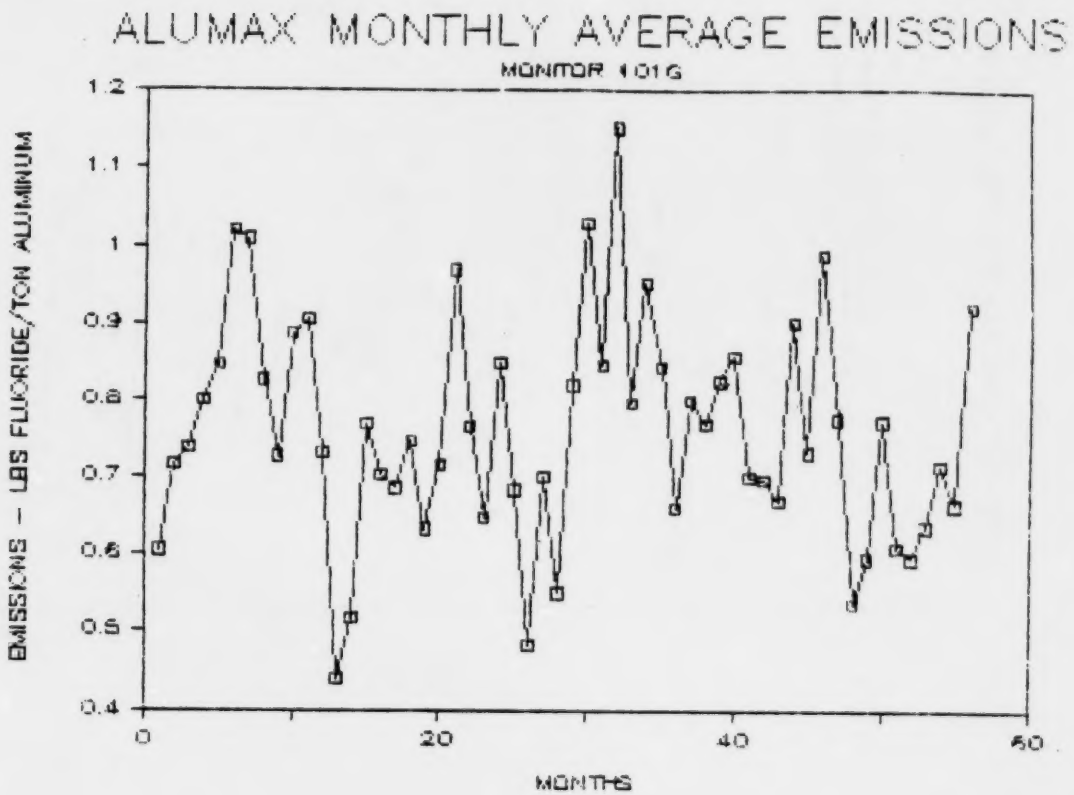


Figure 3-1. ALUMAX Monthly Average Emissions, Roof Monitor 101G

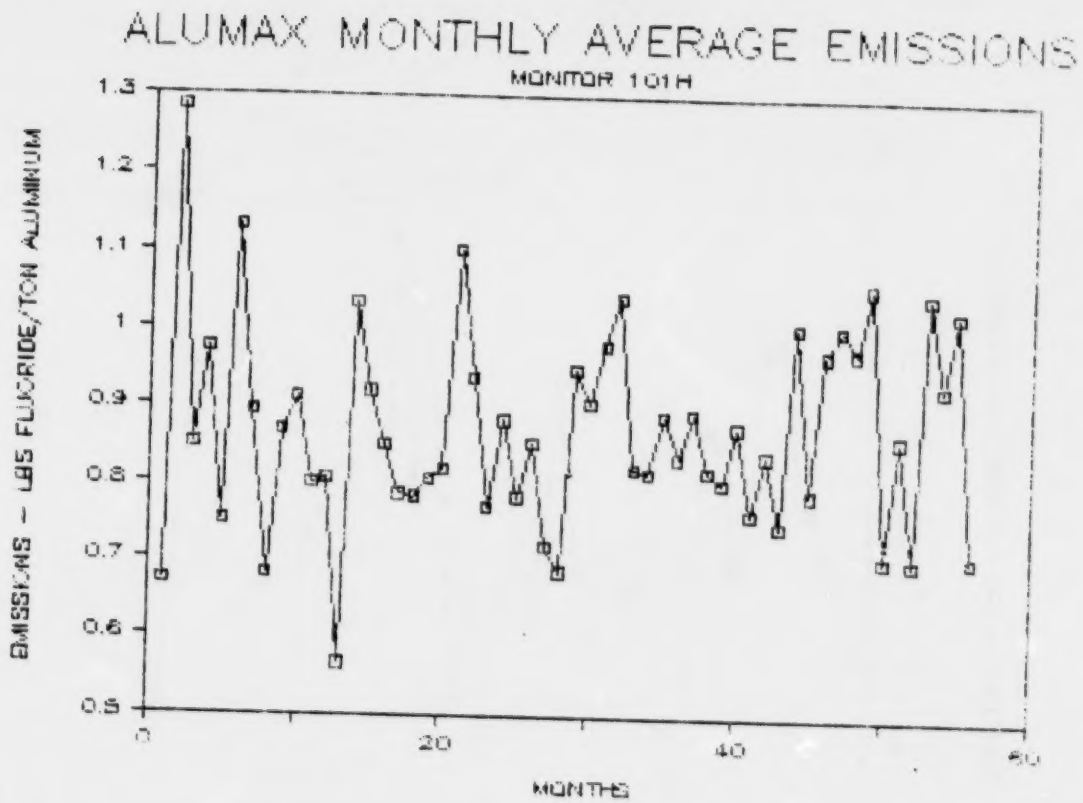


Figure 3-2. ALUMAX Monthly Average Emissions, Roof Monitor 101H

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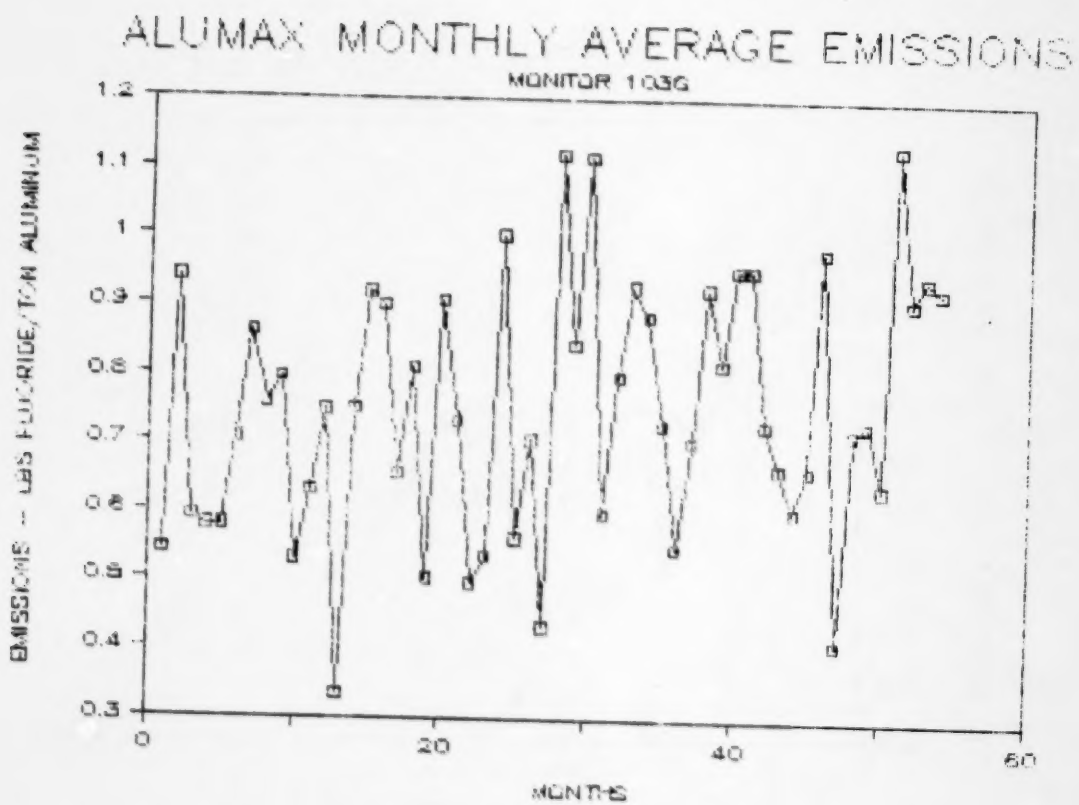


Figure 3-3. ALUMAX Monthly Average Emissions, Roof Monitor 103G

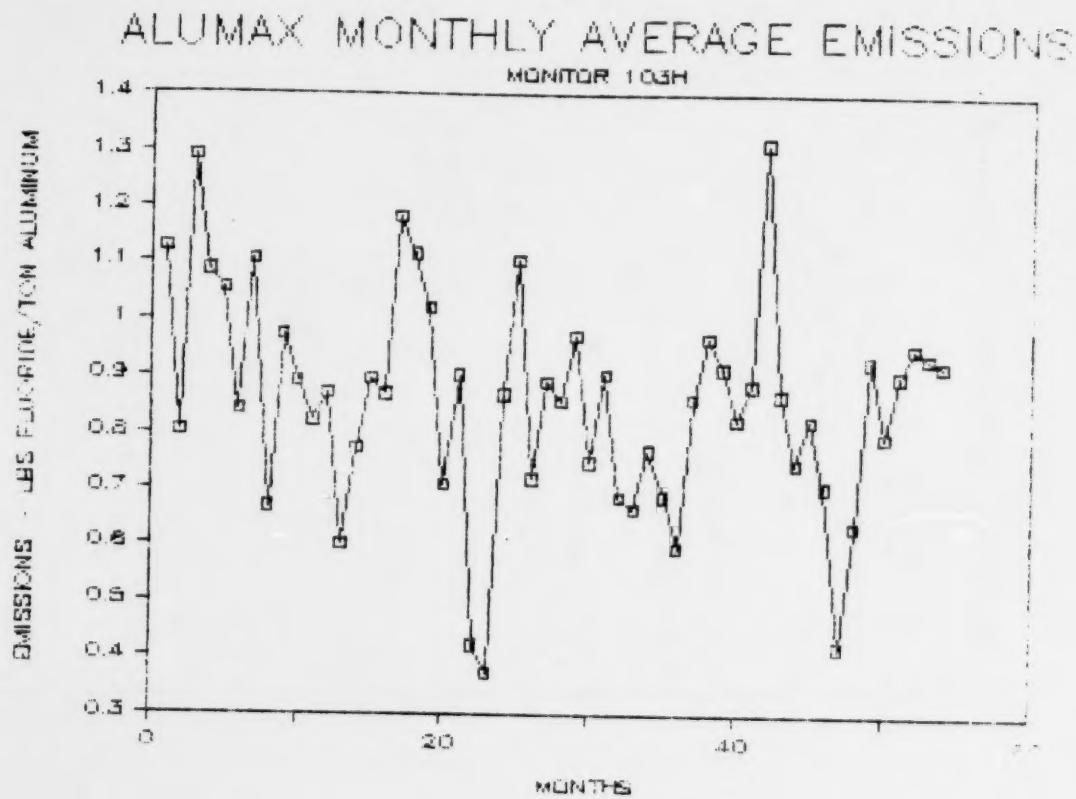


Figure 3-4. ALUMAX Monthly Average Emissions, Roof Monitor 103H

TABLE 3-1. SUMMARY STATISTICS FOR ROOF MONITORS

	XBAR	SX
N of Cases	220	220
Minimum	0.33330	0.01530
Maximum	1.31330	0.52920
Range	0.98000	0.51390
Mean	0.80938	0.14361
Standard Dev	0.17414	0.08298
Skewness	0.01942	1.03680
Kurtosis	0.21706	1.82004

Table 3-2 shows statistics, computed for each roof monitor separately. Roof monitor overall means range from 0.750 to 0.870 of pound fluoride per ton of aluminum produced (lb F/T Al) while the standard deviation mean values range from 0.121 to 0.165 lb F/T Al.

Further detail is given in Table A-3 in the Appendix, Section 6.0, in which the ALUMAX roof monitor data are further subdivided by roof monitor by year. These results are summarized in Figures 3-5 through 3-8. Figure 3-5 shows roof monitor annual averages for Roof Monitors 101G and 101H, both of which are in the same building at the Mount Holly plant. The overall means (from Table 3-2) are also shown on the figures. Note that the annual means for RM101H are significantly larger than those for RM101G. The overall mean for RM101H is about 14 percent higher than that of RM101G. The annual means of the monthly standard deviations for RM101G and 101H are shown in Figure 3-6. No apparent trend is clear, although the overall mean standard deviation for RM101H is about 24 percent higher than the overall mean for RM101G.

Figure 3-7 shows roof monitor annual averages for RM103G and RM103H. Figure 3-8 shows the annual averages of the monthly standard deviations. The overall means for RM103H are larger than the overall means for RM103G (again about 14 percent for the overall monthly means, and 28 percent for the standard deviations). The annual averages for RM103H are again all greater than the annual averages for RM103G for both the emissions and the standard deviations.

To determine if there was a significant difference between the means of the roof monitors, a one way analysis of variance was performed with monitors as treatments. The results are given in Table A-4 of the Appendix and show that there is a significant difference between the mean values of the monitors, at less than the 0.001 level of significance (i.e., >99.9% probability). The overall means of the roof monitor emissions were tested by the least significant difference method, or lsd method, to determine which means differed from each other.[3] The calculations are given in Table A-5 in the Appendix and are summarized in Table 3-3. The table also shows a schematic plant layout for the Mount Holly Plant of ALUMAX, showing the relative locations of the roof monitors and dry scrubbers. The paired difference table shows differences of the overall monitor means and

TABLE 3-2. SUMMARY STATISTICS FOR EACH ROOF MONITOR

THE FOLLOWING RESULTS ARE FOR: RM$[a] = 101G

TOTAL OBSERVATIONS: 56

	XBAR	SX
N of Cases	56	56
Minimum	0.43940	0.01970
Maximum	1.15330	0.31190
Range	0.71400	0.29220
Mean	0.76001	0.13281
Standard Dev	0.14596	0.07367
Skewness	0.26243	0.95984
Kurtosis	0.01560	0.20925

THE FOLLOWING RESULTS ARE FOR: RM$ = 101H

TOTAL OBSERVATIONS: 56

	XBAR	SX
N of Cases	56	56
Minimum	0.56600	0.01990
Maximum	1.28500	0.32600
Range	0.71900	0.30610
Mean	0.86961	0.16486
Standard Dev	0.86961	0.16486
Skewness	0.51151	0.40070
Kurtosis	0.60766	-0.71778

THE FOLLOWING RESULTS ARE FOR: RM$ = 103G

TOTAL OBSERVATIONS: 54

	XBAR	SX
N of Cases	54	54
Minimum	0.33330	0.01530
Maximum	1.13000	0.44030
Range	0.79670	0.42500
Mean	0.74987	0.12129
Standard Dev	0.020989	0.08647
Skewness	0.02584	1.24572
Kurtosis	-0.60669	2.02579

THE FOLLOWING RESULTS ARE FOR: RM$ = 103H

TOTAL OBSERVATIONS: 54

	XBAR	SX
N of Cases	54	54
Minimum	0.37000	0.03540
Maximum	1.31330	0.52920
Range	0.94330	0.49380
Mean	0.85761	0.15511
Standard Dev	0.19465	0.08325
Skewness	-0.14520	1.75156
Kurtosis	0.47816	6.06089

[a]RM$ = 101G is the designation for ALUMAX Roof Monitor 101G.

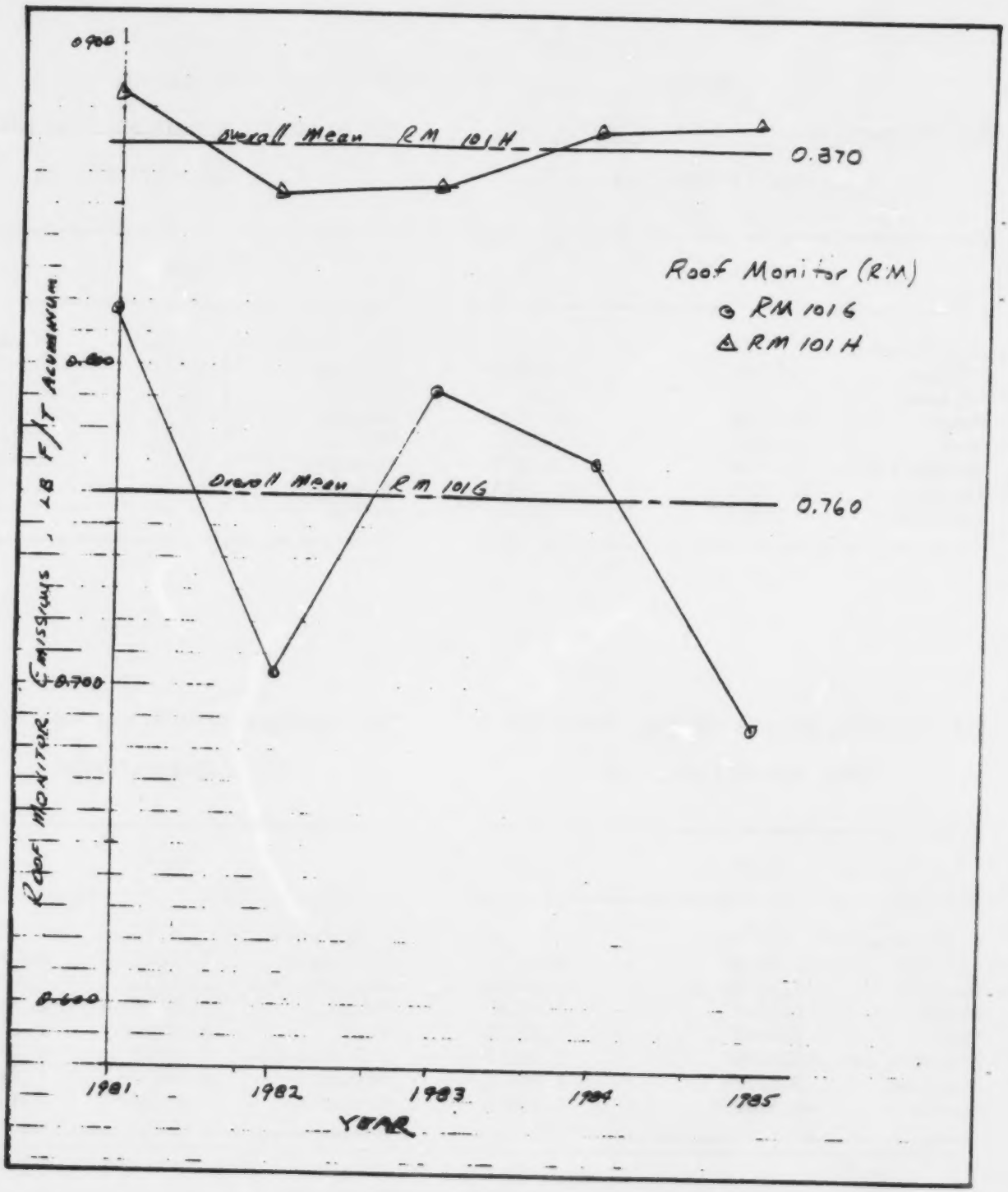


Figure 3-5. Roof Monitor Annual Average, Potline 101.

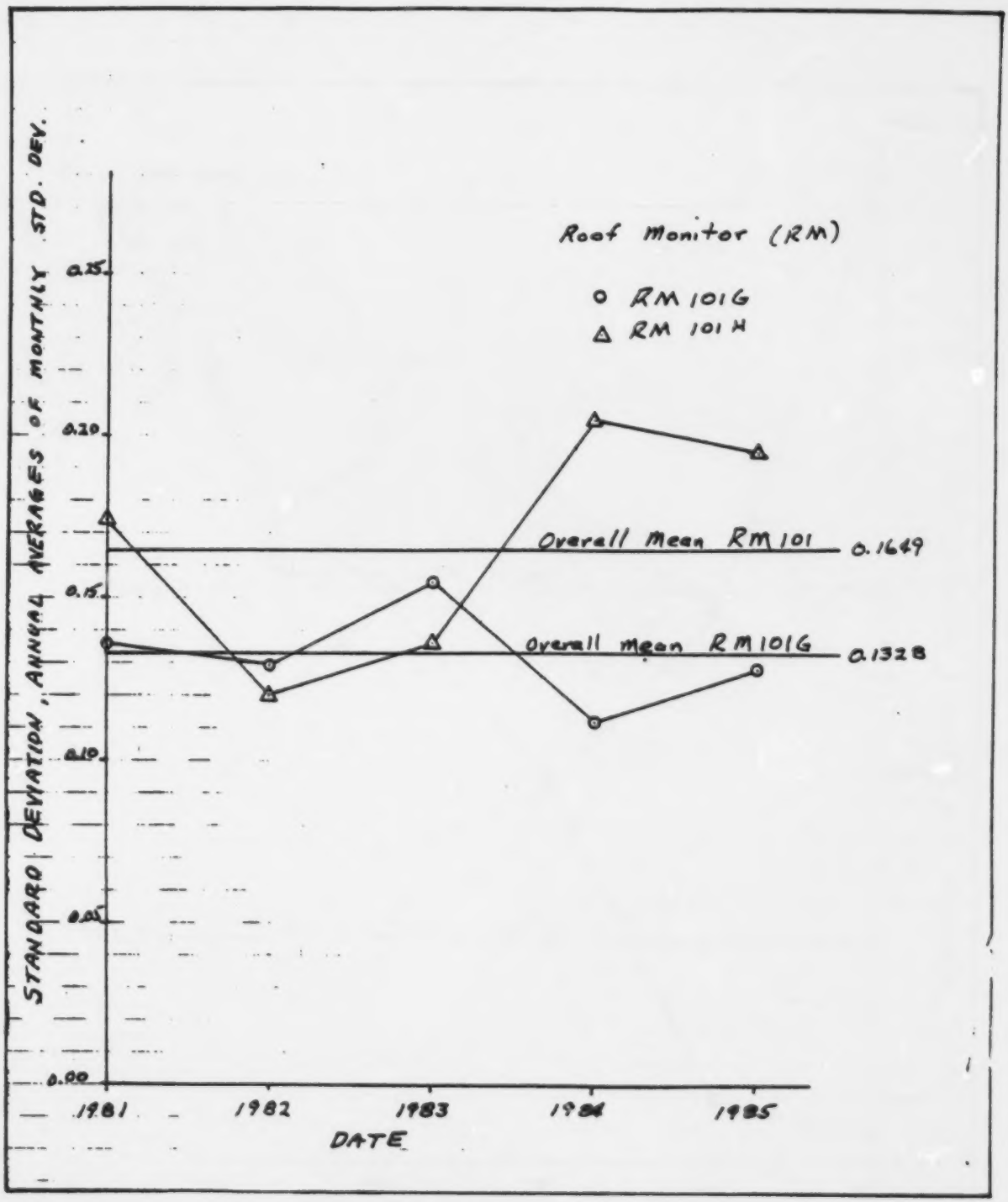


Figure 3-6. Roof Monitor Annual Average of Monthly Standard Deviations, Potline 101.

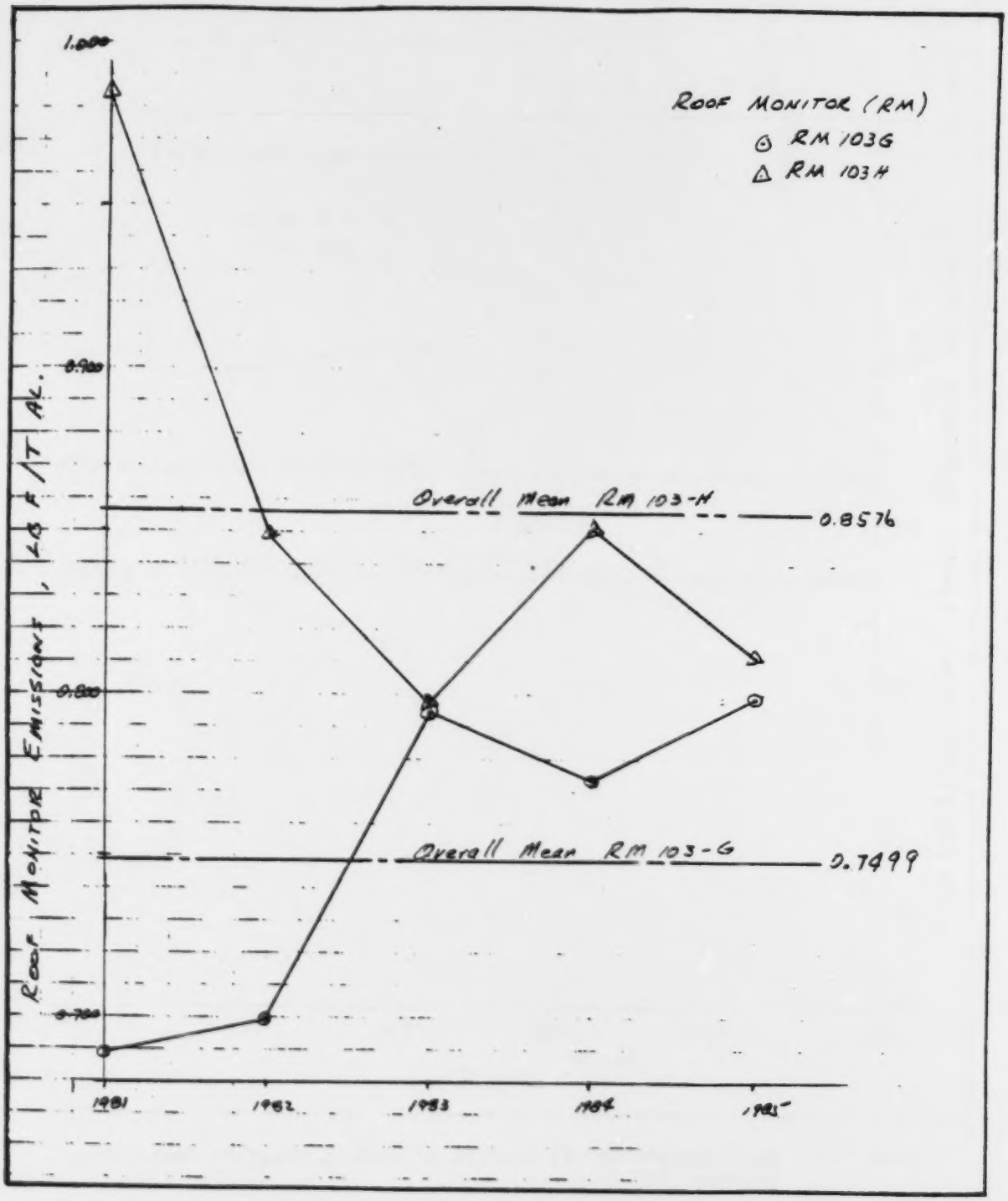


Figure 3-7. Roof Monitor Annual Averages, Potline 103

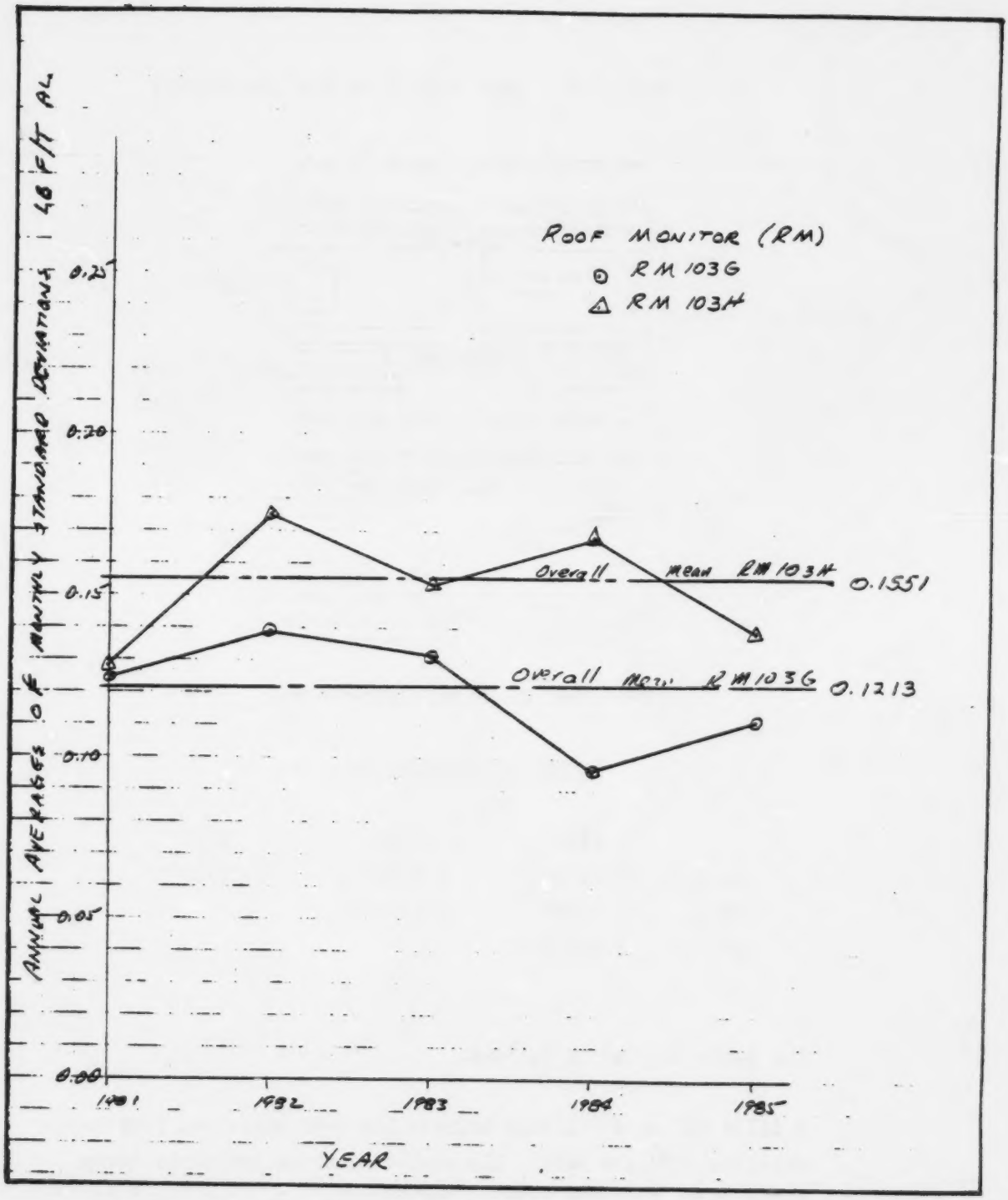
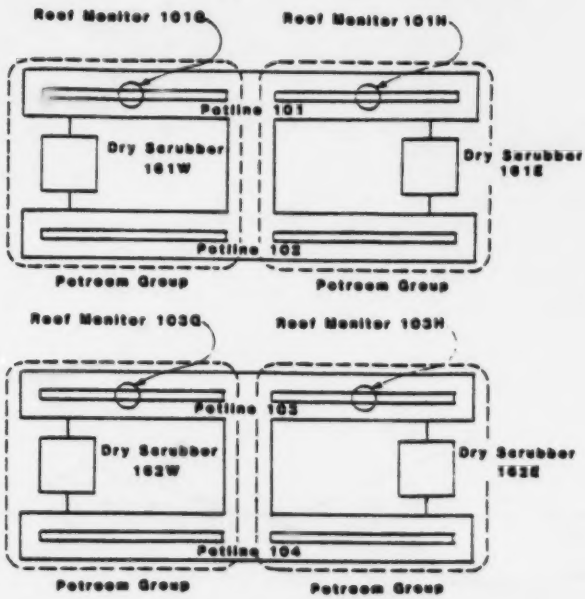


Figure 3-8. Roof Monitor Annual Averages of Monthly Standard Deviations, Potline 103.

TABLE 3-3. ROOF MONITOR PAIRED COMPARISONS



ROOF MONITOR PAIRED COMPARISONS

Paired Difference Table

	103H	103G	101H
101 G	0.09760**	0.01014	0.10960**
101 H	0.01200	0.11974**	
103 G	0.10774**		

The Table is read as follows:

0.10774 is the difference between the mean emissions from Roof Monitors 103H and 103G. The double asterisk indicates those differences that are highly significant, i.e., the level of significance is less than 0.01 (probability >0.99).

indicates which differences are significantly different from zero and which are not. The difference comparisons can be verified qualitatively by reviewing the emission levels indicated in Figures 3-5 and 3-7.

The results of these analyses suggest that the roof monitors should be treated separately in the modeling phase of this study rather than attempting to pool the data of all four monitors.

3.2 DRY SCRUBBER DATA

Table 3-4 give summary statistics for all four dry scrubbers combined. Note that the overall mean XBAR for the dry scrubber is less than one-tenth that of the overall mean XBAR for the roof monitors. The mean standard deviation of the dry scrubber emissions data is about one-fifth that of the roof monitor data. The overall dry scrubber mean is 0.07443 lb F/T Al and the mean standard deviation is 0.02856 lb F/T Al. The data do not appear to exhibit a consistent or significant skewness, and the kurtosis is near that of a normal distribution (= 3.0 for the normal distribution).

Table 3-5 gives statistics for each dry scrubber. The means range from 0.046 to 0.101 lb F/T Al, and the standard deviations calculated from the daily emissions used for the monthly means range from 0.015 to 0.034 lb F/T Al.

The paired difference table for dry scrubbers is shown below:

Paired Difference Table

	162E	162W	161E
161W	0.01319	0.02212	0.04102*
161E	0.05421**	0.01840	
162W	0.03531*		

The Table is read as follows:

0.05421 is the difference in the overall mean emissions for dry scrubbers 161E and 162E. The double asterisk indicates the difference to be highly significant at the 0.01 level (probability >99%). The single asterisk denotes a significance level at least 0.05 (probability >95% but <99%). No asterisk accompanying a difference indicates the difference is not significantly different from zero.

The analysis of variance which is reported in Table A-6 in the appendix indicates that there is a highly significant difference (P=0.004) in the mean emissions between dry scrubbers. Table A-7 gives calculations to show which dry scrubbers differ.

3.3 DATA DISTRIBUTION

A key consideration in developing a model for predicting emissions from potroom groups in primary aluminum plants is to determine the frequency distribution of the data. ALUMAX has asserted that they believe the emissions data to follow a lognormal distribution.

The analysis given below for the roof monitors indicates that the roof monitor data follow a normal distribution rather than a lognormal distribution. Much continuous emission data are lognormally distributed,

TABLE 3-4. SUMMARY STATISTICS FOR DRY SCRUBBERS

	XBAR	SX
N of Cases	72	72
Minimum	0.01500	0.00150
Maximum	0.26270	0.18870
Range	0.24770	0.18720
Mean	0.07443	0.02856
Standard Dev	0.05017	0.03559
Skewness	1.50491	2.24836
Kurtosis	2.36320	5.57309

TABLE 3-5. SUMMARY STATISTICS FOR EACH DRY SCRUBBER

THE FOLLOWING RESULTS ARE FOR: DS$[a] = 161E

TOTAL OBSERVATIONS: 19

	XBAR	SX
N of Cases	19	19
Minimum	0.01500	0.01500
Maximum	0.08200	0.06580
Range	0.06700	0.06430
Mean	0.04634	0.01488
Standard Dev	0.02208	0.01843
Skewness	0.19063	2.19785
Kurtosis	-1.22424	3.46346

THE FOLLOWING RESULTS ARE FOR: DS$= 161W

TOTAL OBSERVATIONS: 19

	XBAR	SX
N of Cases	19	19
Minimum	0.01870	0.00170
Maximum	0.26270	0.18870
Range	0.24400	0.18700
Mean	0.08736	0.04161
Standard Dev	0.06443	0.04815
Skewness	1.33261	1.66006
Kurtosis	1.17746	2.51859

THE FOLLOWING RESULTS ARE FOR: DS$ = 162E

TOTAL OBSERVATIONS: 17

	XBAR	SX
N of Cases	17	17
Minimum	0.03800	0.00300
Maximum	0.21970	0.14240
Range	0.18170	0.13940
Mean	0.10055	0.03396
Standard Dev	0.05059	0.03747
Skewness	0.72971	1.75293
Kurtosis	-0.15357	2.40400

THE FOLLOWING RESULTS ARE FOR: DS$ = 162W

TOTAL OBSERVATIONS: 17

	XBAR	SX
N of Cases	17	17
Minimum	0.02070	0.00450
Maximum	0.16100	0.10580
Range	0.14030	0.10130
Mean	0.06524	0.02385
Standard Dev	0.03797	0.02731
Skewness	1.18821	2.05867
Kurtosis	0.59005	3.25029

[a]DS$ = 161E is the designation for ALUMAX Dry Scrubber 161E.

however the ALUMAX data are monthly averages of two or three consecutive days' testing. The analyses given below indicate the roof monitor data to be approximately normally distributed.

Figure 3-9a is a probability plot of all the roof monitor data combined. The ordinate is the expected normal value of that observation for the standard normal distribution, with a mean of 0 and variance of 1, and the abscissa is the monthly mean, XBAR. If the data are from a normal distribution, the plotted values will lie on a straight line. In Figure 3-9a, at an expected value of zero the XBAR value is seen to be about 0.8. On a cumulative scale, the zero on the ordinate of the diagram represents 50 percent of the distribution, which is the median. The upper plot therefore shows that approximately 50 percent of the XBAR values are less than 0.8 lb F/T Al. Table 3-1 gave the overall mean $\bar{X}$ = 0.80938. For a normal distribution the mean and the median are coincident and occur at the most frequent value, or for a cumulative distribution they occur at the 50 percent probability level. Asterisks on the plot indicate that one datum occurs at the point plotted while the numbers 2 through 9 indicate the number of data occurring at the indicated point.

An additional plot of the data which graphically tests the hypothesis of normality is given in Figure 3-9b. The detrended normal probability plot shows the differences between the expected normal values and the standardized value of the observation. Note that the vast majority of the monthly mean emissions data hover around zero (±0.2). If the data follow a normal probability distribution exactly, all the points would be plotted at "DEVIATION FROM EXPECTED VALUE" equal to zero.

Figure 3-10a plots the roof monitor mean monthly emission data on the same scale after having transformed XBAR to the logarithm (base e), LXBAR. If the data followed a lognormal distribution, the curve would be linear. A concave upward trend is visually apparent in Figure 3-10a. The deviation from the expected value for LXBAR (Figure 3-10b) and shows much more curvature. These graphical tools are evidence that the mean monthly roof monitoring data are normally distributed.

Figures 3-11 and 3-12 show stem-and-leaf plots[5] of XBAR and LXBAR, respectively. The plots are essentially frequency histograms rotated 90° clockwise from the usual frequency diagrams. The value of a stem-and-leaf display is that actual numerical values (to two significant digits past the

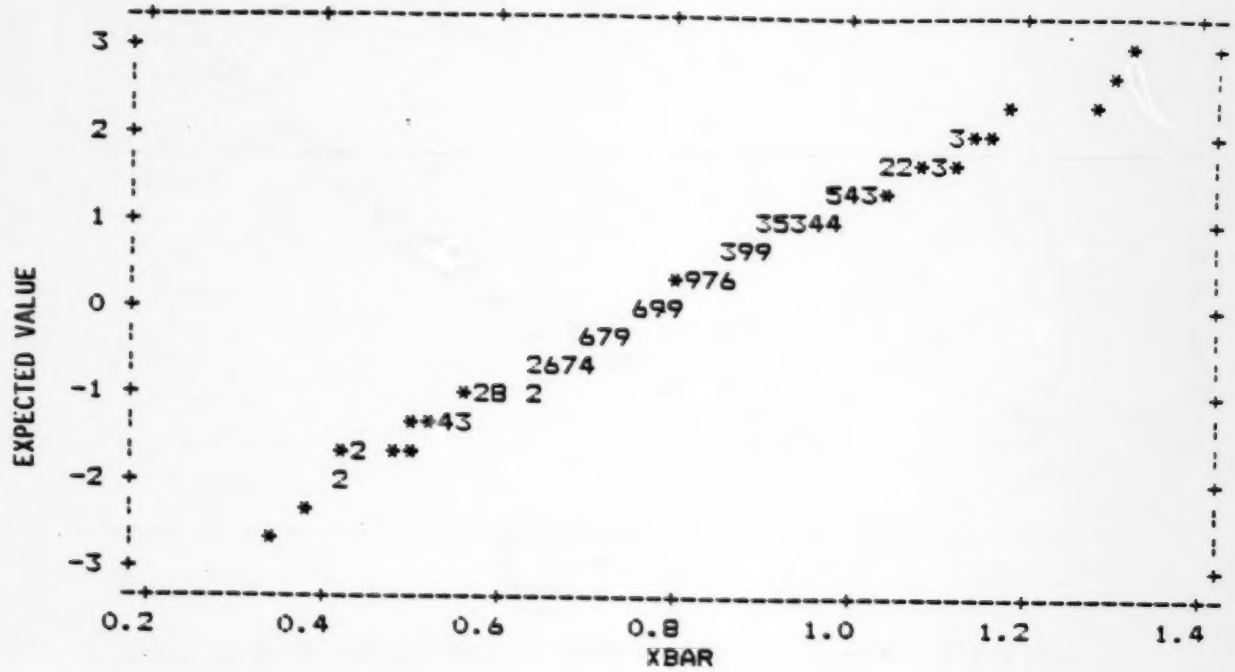


Figure 3-9a. Normal Probability Plot of Roof Monitor Monthly Means

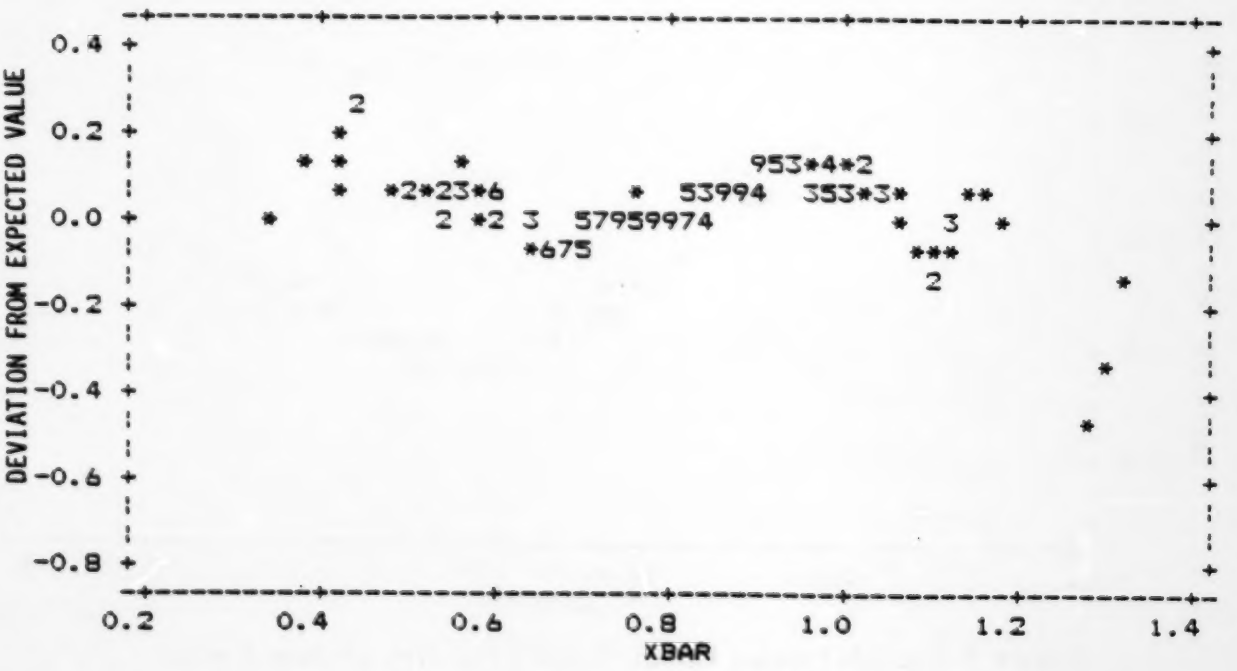


Figure 3-9b. Detrended Normal Probability Plot of Roof Monitor Monthly Means

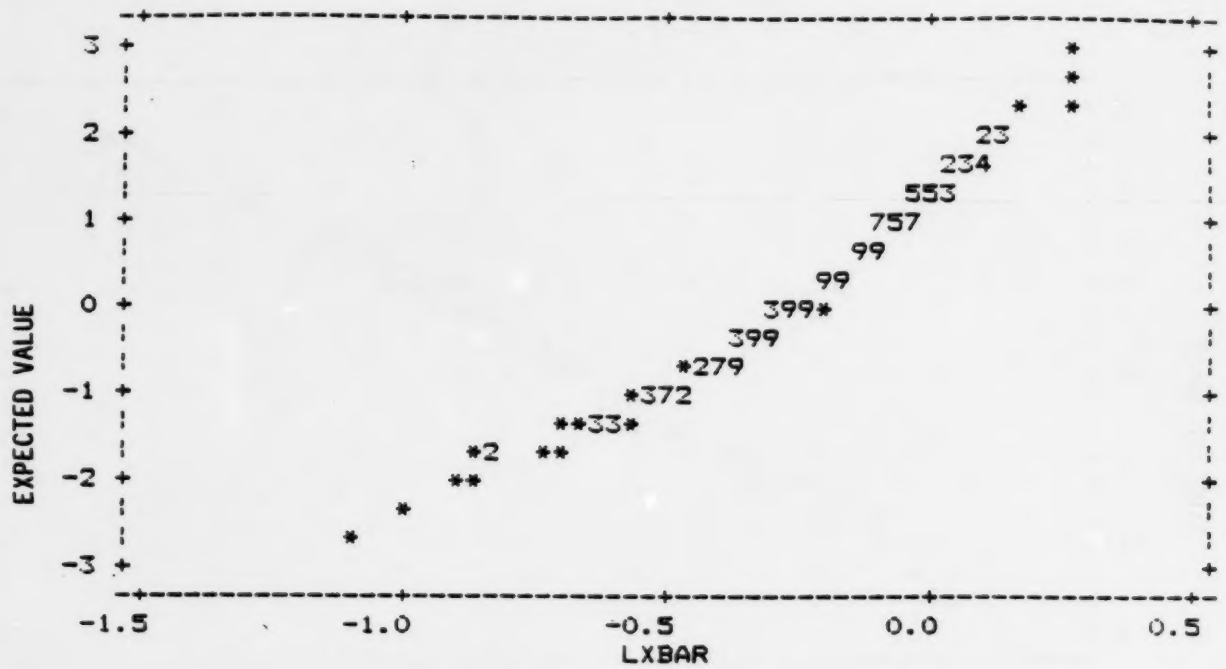


Figure 3-10a. Normal Probability Plot of Roof Monitor Monthly Means

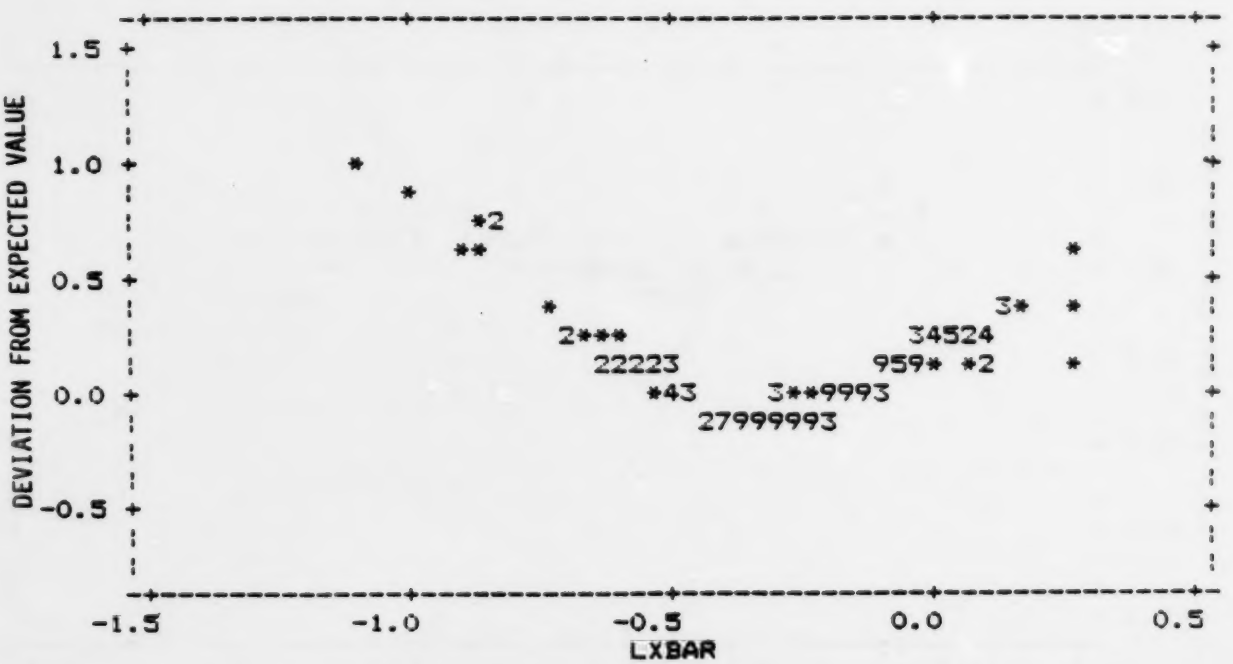


Figure 3-10b. Detrended Normal Probability Plot of Room Monitor Monthly Means

STEM-AND-LEAF PLOT OF VARIABLE: XBAR

SMALLEST VALUE AT TOP OF PLOT IS: 0.333

```
     3   37
***OUTSIDE VALUES***
     4   12233
     4   89
     5   013334
     5   556688999
     6   000003334
     6   566666778888899
     7 H 00000000111122233333334444
     7   5555667777777888999
     8 M 000000001112222222223444444
     8   555566666777777888899999
     9 H 000000011222334
     9   55557777777889
    10   000122334
    10   558
    11   00011223
    11   58
***OUTSIDE VALUES***
    12   89
    13   1
```

Figure 3-11. Monthly Mean Values of the Four Roof Monitors, 1b F/T A1.

```
STEM-AND-LEAF PLOT OF VARIABLE:          LXBAR

SMALLEST VALUE AT TOP OF PLOT IS:        -1.099

      -10   9
       -9   9
       -8   96632
  ***OUTSIDE VALUES***
       -7   2
       -6   985
       -6   3221
       -5   9976
       -5   442111000
       -4   9555
       -4   32110000
       -3 H 9887777655555
       -3   4444333221111110
       -2 M 99988887766666555
       -2   44332222221111100
       -1   9999999997777766666555
       -1 H 44433333322222111110000
       -0   9999988877665
       -0   4443332222221
        0   000011234
        0   5589
        1   00111224
        1   6
        2
        2   557
```

Figure 3-12. Logarithm of the Monthly Means of the Four Roof Monitors

decimal) are given in the display. The "stems" are the numbers in the vertical column (3 through 13) representing XBAR from (0.3 to 1.3). The leaves are the numbers on the right of the empty space next to the stems and represent the actual XBAR values. For example in the first row at the top of the plot "3 37" means that the smallest XBAR - 0.33 and the next larger value of XBAR = 0.37.

The locations of the median (M) and the hinges (H) are indicated by the M or H's in the area between the stem and leaves. The median splits the sorted or ordered data in half, and the hinges split each half once more. M is printed on the line which includes the actual value of the median, i.e., the median lies between 0.80 and 0.84. H is printed on the stems containing the hinges. The "H-Spread" is the difference between the values of the two hinges. The "inner fences" are defined as follows:

lower fence = lower hinge - (1.5 X H-Spread)

upper fence = upper hinge + (1.5 X H-Spread)

Any values outside the inner fences are printed on separate lines and separated from the inner values by a line of text: ***OUTSIDE VALUES***.

Figure 3-11 shows the XBAR values to be approximately symmetrically distributed about the median (or mean) value M. Figure 3-12 shows the logarithm of XBAR (LXBAR) to be skewed (a longer tail...) to the top or the small values of LXBAR. A lognormal distribution is skewed toward the larger values of LXBAR which is opposite to the skew of Figure 3-12. These figures provide additional evidence that the normal distribution represents the roof monitor average monthly emission data better than the lognormal distribution.

Finally, XBAR and LXBAR were tested for goodness of fit using the Kolmogorov D statistic.[6] The results of the test are given in Table 3-6 for the combined data and by roof monitor and indicate that for Roof Monitors 101G, 101H, and 103G, there is no significant difference between the normal and lognormal distributions. For Roof Monitor 103H and the combined data, however, the test indicates there is a significant difference between the sample and hypothesized distribution for the lognormal distribution. The computer printouts of the Kolmogorov D statistic tests are given in the Appendix, Table A-8. Table 3-6 also shows that for the combined roof monitor data the Kolmogorov D test suggests that the overall roof monitor emissions

TABLE 3-6. KOLMOGOROV D[a] TEST FOR GOODNESS OF FIT[b]

Roof Monitor	XBAR[c]	LXBAR[d]
Combined Data	n.s.	s.
101G	n.s.	n.s.
101H	n.s.	n.s.
103G	n.s.	n.s.
103H	n.s.	s.

[a] D is calculated as the maximum absolute difference between the hypothesized cumulative distribution and the sample cumulative distribution over all data points.

[b] n.s. - indicates the Kolmogorov D statistic is not significantly large to warrant rejection of the null hypothesis, H_o at a 0.05 significance level.

s. - indicates D statistic to be significantly large; i.e., can reject H_o at a 0.05 significance level.

[c] H_o: XBAR data fits a normal distribution.

[d] H_o: LXBAR data fits a normal distribution.

data fit a normal distribution but do not fit a lognormal distribution. The conclusion drawn from the analyses given here is that the roof monitor data fit a normal frequency distribution as well as or better than a lognormal distribution.

3.4 TIME SERIES ANALYSIS

To investigate the autocorrelation structure of the roof monitor data, the autocorrelation functions (ACF) and the partial autocorrelation (PACF) functions[4,7] were calculated and given in Tables A-9 through A-12 in the Appendix. Tables A-10 and A-11 show that the emissions data exhibit no significant autocorrelation structure, whereas Tables A-9 and A-12 indicate a very weak autocorrelation structure--the first order autocorrelation coefficients, ρ_1, equal 0.333 and 0.282, for roof monitors 101G and 103H, respectively. These values for the four roof monitors are so low as to indicate that a random model would be appropriate, i.e., no autocorrelation structure should be incorporated into the model. The autocorrelation functions and partial autocorrelation functions were also calculated for the monthly standard deviations. The plots of ACF and PACF for the monthly standard deviations which are given in Tables A-13 through A-16 in the Appendix show no autocorrelation whatsoever and suggest that the standard deviations are independent of time.

As indicated earlier, there were an insufficient number of consecutive readings of the dry scrubber emission data to do a meaningful time series analysis. A minimum number of about 50 is recommended.[7] It will therefore be assumed that the dry scrubber emissions data are independent of time, and normally distributed. The fact that the roof monitor data were found not be autocorrelated adds credence to this assumption.

3.5 COVARIANCE OF THE ROOF MONITOR AND DRY SCRUBBER DATA

The analysis given above all point toward a random, time independent model which will be discussed in Section 4 below. Because the primary aluminum NSPS specifies 1.9 lb F/T Al as the maximum emission rate of fluoride from a potroom group, it is necessary to add the roof monitor emissions to the dry scrubber emissions in order to obtain the emissions from the potroom group.

The sum of the monthly means of the roof monitor emissions and the monthly means of the corresponding dry scrubbers will be defined as:

$$\bar{X} = \bar{X}_1 + \bar{X}_2, \qquad (3\text{-}1)$$

where:

$\bar{X}$ = monthly mean emissions from a potroom group.

$\bar{X}_1$ = monthly mean emissions from the roof monitor of the potroom group, and

$\bar{X}_2$ = monthly mean emissions from the dry scrubber of the potroom group.

The estimate of the variance of the sum of the variables is:

$$S^2_{\bar{x}} = S^2_{\bar{x}1} + S^2_{\bar{x}2} + 2\, r\, S_{\bar{x}1}\, S_{\bar{x}2} \qquad (3\text{-}2)$$

where,

$S^2_{\bar{x}}$ = the estimate of the variance of $\bar{x}$,

$S^2_{\bar{x}1}$ = the estimate of the variance of $\bar{x}_1$,

$S^2_{\bar{x}2}$ = the estimate of the variance of $\bar{x}_2$,

r = the correlation coefficient of $\bar{x}_1$ and $\bar{x}_2$, and

$r\, S_{\bar{x}1}\, S_{\bar{x}2}$ = the covariance between $\bar{x}_1$ and $\bar{x}_2$.

The purpose of this section is to determine if there exists a significant correlation between the monthly mean roof monitor emissions and the monthly mean dry scrubber emissions. If there is insignificant correlation, the covariance term in the calculation of the variance of the total monthly emissions will be assumed equal to zero.

The calculations of the covariance matrices for roof monitor and dry scrubber emissions in the same potroom group are given in Table A-21 of the Appendix. The roof monitor variances, the dry scrubber variances, their covariances, and the coefficients of correlation are listed in Table 3-7. The data show that the covariance of the Roof Monitor 103H-Dry Scrubber 162E

TABLE 3-7. VARIANCES AND COVARIANCES OF ROOM MONITOR AND DRY SCRUBBER EMISSIONS

Roof Monitor Dry Scrubber Pair	Variance of $\bar{X}_1$, $S^2_{\bar{x}1}$	Variance of $\bar{X}_2$, $S^2_{\bar{x}2}$	Covariance of $\bar{X}_1$ $\bar{X}_2$, $S_{\bar{x}1\bar{x}2}$	Coefficient[a] of Correlation, r	Number of Observations
RM101G-DS161W	0.023900	0.004151	0.000675	0.06777	19
RM101H-DS161E	0.027373	0.000487	0.000143	0.03909	19
RM103G-DS162W	0.024500	0.001442	0.000278	0.04677	17
RM103H-DS162E	0.033458	0.002560	0.004384	0.47375[b]	17

[a] $r = S_{\bar{x}1\,\bar{x}2} / (S_{\bar{x}1} \cdot S_{\bar{x}2})$

[b] the value of r = 0.47375 is not significantly different [3] from zero based on 15 degrees of freedom

pair is apparently much larger than the covariance of the other roof monitor-dry scrubber pairs. However, a statistical test of significance indicates that the coefficient of correlation for the Roof Monitor 103H-Dry Scrubber 162E pair is not significantly different from zero.

The determination that none of the correlation coefficients between the roof monitor-dry scrubber pairs within a potroom group is significantly different from zero supports the assumption, but does not guarantee, that within a potroom group the roof monitor - dry scrubber emissions are independent of one another.

3.6 CHOICE OF DATA BASE

To summarize the results of the studies given in Sections 3.1 through 3.5, the following conclusions may be drawn:

- There is a significant difference between means of monthly roof monitor data.
- There is a significant difference between the means of monthly standard deviations of the roof monitor data.
- There is a significant difference between the means of the dry scrubber emissions.
- There is a significant difference between the monthly means and standard deviations of potroom groups.
- The roof monitor monthly means are normally distributed.
- The roof monitor monthly means and monthly standard deviations are independent of time.
- There is no significant correlation between the means of the roof monitors and the dry scrubbers in the same potroom group.

In view of the results reported above it is recommended that the proposed model simulate the potroom group emissions for each pair of roof monitors and dry scrubbers separately.

4.0 PROPOSED EMISSIONS MODEL

The data analysis results from Task 1 (see Section 3) indicate that the probability of exceedance (of a 1.9 standard) for the Alumax plant can be determined analytically as a function of $\bar{X}$ and $S_{\bar{X}}$ for each potroom group. An analytical determination of the probability of exceedance is appropriate for the following reasons:

1. The monthly average emissions from the potroom groups exhibit insignificant autocorrelation; and
2. The monthly average emissions from the potroom groups are normally distributed.

4.1 EMISSIONS MODEL AND PROBABILITY-OF-AN-EXCEEDANCE RELATION

The probability graph is independent of the potroom group and depends only on the data's not being autocorrelated and their having a normal distribution. The emissions model for the ALUMAX data is developed below, and the derivation and construction of the Probability-of-an-Exceedance graph is explained. The use of the Probability-of-an-Exceedance graph in regulatory procedures is explained in Sections 5 and 6.

The proposed statistical methodology for determining the probability of exceedance vs. $\bar{X}$ and $S_{\bar{X}}$ for each potroom group is based on the emission characteristics derived for the ALUMAX data, as follows:

1. Assume monthly average emissions from roof monitors, denoted by $\bar{X}_1$, are normally distributed.
2. Assume monthly average emissions from the dry scrubbers, denoted $\bar{X}_2$ are normally distributed.
3. Assume $\bar{X}_1$ and $\bar{X}_2$ are independently distributed. Therefore, monthly mean emissions from a potroom group, $\bar{X} = \bar{X}_1 + \bar{X}_2$, will be normally distributed with mean,

$$\bar{X} = \bar{X}_1 + \bar{X}_2 \qquad (4\text{-}1)$$

and variance,

$$S^2_{\bar{x}} = S^2_{\bar{x}1} + S^2_{\bar{x}2} \qquad (4\text{-}2)$$

where:

$\bar{\bar{X}}$ = monthly mean emissions from a potroom group,

$\bar{X}_1$ = monthly mean emissions from the roof monitor(s) of the potroom group,

$\bar{X}_2$ = monthly mean emissions from the dry scrubber(s) of the potroom group,

$\bar{\bar{X}}$ = overall mean of the monthly mean emissions from a potroom group,

$S^2_{\bar{x}}$ = estimate of the variance of the monthly mean emissions from a potroom group,

$S^2_{\bar{x}1}$ = estimate of the variance of the monthly roof monitor mean emission over a period of time, and

$S^2_{\bar{x}2}$ = estimate of the variance of the monthly means emission of the dry scrubber emissions over the same period of time as $S^2_{\bar{x}}$.

4. The probability (Pr) that a monthly average total emission value, $\bar{\bar{X}}$, will exceed the standard of 1.9 lb/ton aluminum can be calculated as follows:

$$Pr\ (\bar{\bar{X}} > 1.9) = Pr\left(\frac{\bar{\bar{X}} - \mu_{\bar{\bar{x}}}}{\sigma_{\bar{\bar{x}}}} > \frac{1.9 - \mu_{\bar{\bar{x}}}}{\sigma_{\bar{\bar{x}}}} \right)$$

$$Pr\left((Z) > \frac{1.9 - \bar{\bar{X}}}{S_{\bar{\bar{x}}}} \right)$$

where;

$\bar{\bar{X}}$ = monthly mean emission value from a potroom group

$\mu_{\bar{\bar{x}}}$ = the true mean of the monthly mean emissions from a potroom group

$\sigma_{\bar{X}}$ = the true standard deviation of the monthly mean emissions from a potroom group

Z = the standard normal random variable

$\bar{\bar{X}}$ = overall mean of monthly mean emissions from a potroom group; an estimate of

$S_{\bar{X}}$ = the standard deviation of the monthly mean emissions from a potroom group; an estimate of $\sigma_{\bar{X}}$.

The probability of Z greater than any value, can be determined from a table for the cumulative normal distribution function.[8] Probabilities may be calculated for any value of $\bar{\bar{X}}$ and $S_{\bar{X}}$ with the method described above.

For example, suppose the overall mean, $\bar{\bar{X}}$ of a hypothetical potroom group Y is 1.3, with $S_{\bar{X}} = 0.2$. Then graphically the normal distribution can be depicted as follows:

The probability of any monthly mean emission exceeding the 1.9 standard would be calculated as follows:

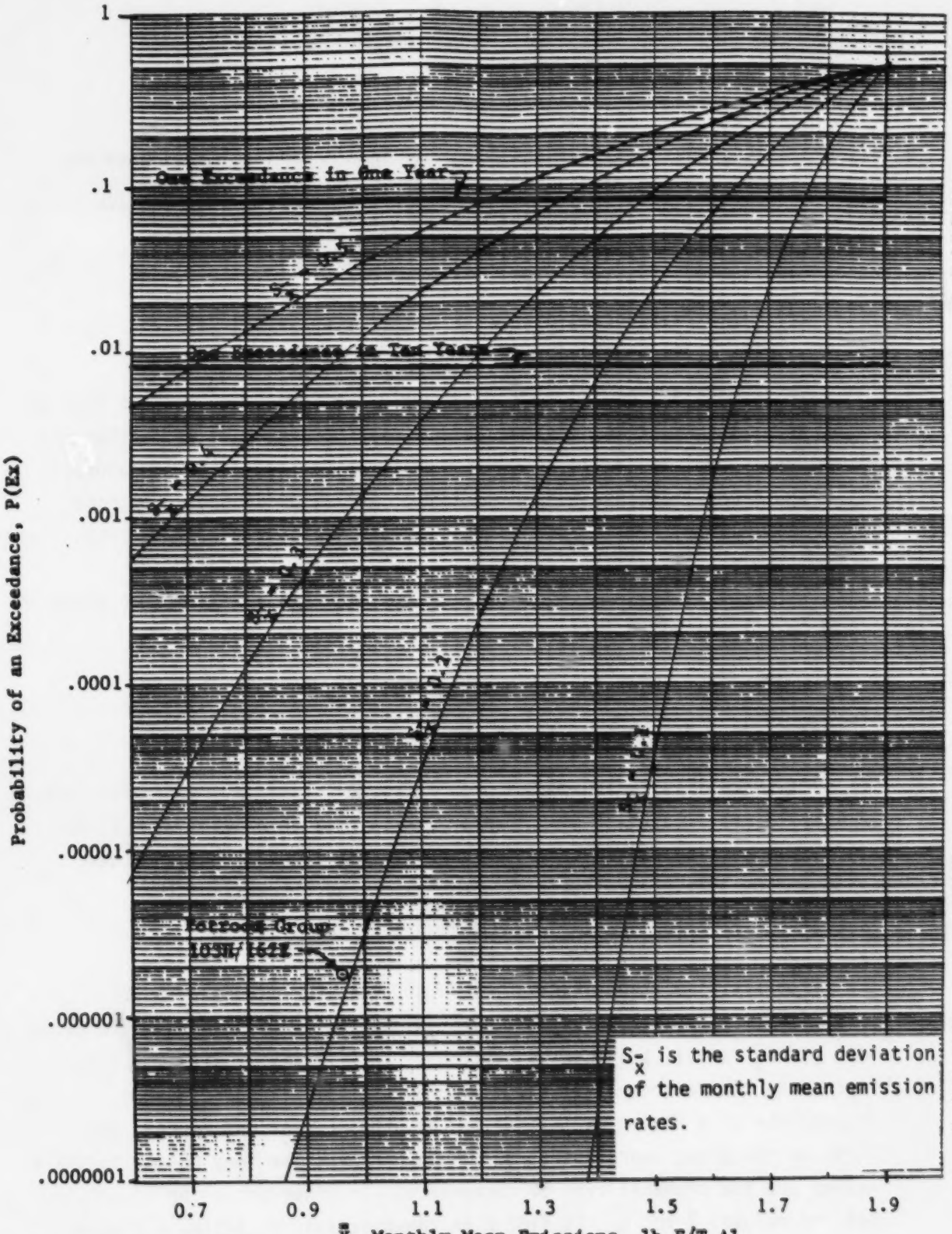
$$Pr\ (\bar{\bar{X}} > 1.9) = Pr\ (Z > ((1.9-1.3)/0.2))$$

$$Pr\ (Z > 3) = 0.0013.$$

The probability value, 0.0013, is found in a table which provides the probability of Z being greater than any value between 0 and 4.99. (Some tables may provide probabilities of Z being less than any value between -4.99 and 0. The probabilities are equivalent as a result of the symmetrical properties of the normal distribution.)

4.2 PROBABILITY-OF-AN-EXCEEDANCE GRAPH AND REQUIREMENTS FOR ITS USE

After the probabilities have been calculated over an appropriate range of $\bar{\bar{X}}$ and $S_{\bar{X}}$ values, they can be plotted as in Figure 4-1. The abscissa represents the various $\bar{\bar{X}}$ values, while the ordinate expresses the probability of a random exceedance of the standard for any month. Each curve on the graph represents the various $S_{\bar{X}}$ values as they relate to the $\bar{\bar{X}}$ values and the probabilities of exceedance. In other words for a certain pair of values, $\bar{\bar{X}}$ and $S_{\bar{X}}$, 1) find $\bar{\bar{X}}$ on the abscissa, 2) follow a straight line up from the abscissa to where it intersects the appropriate curve for the $S_{\bar{X}}$ value and 3) follow a horizontal line from that point of intersection to the ordinate to find the probability of an exceedance.



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Figure 4-1. Probability of an Exceedance

Two horizontal lines are drawn on Figure 4-1 and labeled "ONE EXCEEDANCE IN 10 YEARS," and "ONE EXCEEDANCE IN ONE YEAR." The location of these lines is calculated as follows. In 10 years there would be 120 chances for an exceedance based on a monthly sampling schedule. The probability of one exceedance in 10 years is 1 divided by 120, or 0.008333 which is the level for the line labeled "ONE EXCEEDANCE IN TEN YEARS." For the line labeled "ONE EXCEEDANCE IN ONE YEAR," the probability is 1 divided by 12, or 0.0833.

The $\bar{X}$ and $S_{\bar{x}}$ values for the potroom groups of the ALUMAX plant are presented in Table 4-1 along with the normal Z variate and probability of an exceedance P(Ex).

The location of the potroom groups for the ALUMAX plant is well below the probability of the ONE EXCEEDANCE IN 10 YEARS line. In fact, only potroom group 103H/162E has a probability that can be found in the range of most cumulative normal probability tables. Its probability of exceedance of the standard for any month is 1.8×10^{-6}. Potroom Group 103H/162E is plotted on Figure 4-1. The remaining three potroom groups have a probability of exceedance less that $1X10^{-7}$. This means that *by random variation alone*, at the ALUMAX plant one might expect that there would be no more than one exceedance per 100,000 years. It should be emphasized that Figure 4-1 accounts for random variation only. Figure 4-1 is not valid if:

- There is equipment failure at the plant;
- The plant operating conditions and procedures change; or
- There is a change in the regular maintenance and cleanup routines.

The following requirements must be fulfilled before using Figure 4-1 to provide probabilities of exceedance for a given potroom group's data:

1. A sufficient number of monthly observations must be available, no less than three years to identify the distributional properties and no less than four years to identify the existence of any auto correlation structure. The analysis of the ALUMAX data has lead to the belief that perhaps random monthly mean observations would not exhibit significant autocorrelation structure for the same type primary aluminum potroom group as the ALUMAX facility.

TABLE 4-1. PROBABILITY OF AN EXCEEDANCE, ALUMAX POTROOM GROUP.

POTROOM GROUP	$\bar{X}$	$S_{\bar{X}}$	Z	P(Ex)
101G/161W	0.8473	0.1520	6.926	$<1x10^{-7}$
101H/161E	0.9162	0.1340	7.342	$<1x10^{-7}$
103G/162W	0.8070	0.2114	5.170	$<1x10^{-7}$
103H/162E	0.9618	0.2024	4.635	1.8×10^{-6}

However, each new plant's emission data needs to be tested for seasonal or other types of autocorrelation structure before using Figure 4-1 as a basis for authorizing a reduced sampling schedule.

2. The monthly average emissions from a plant's roof monitors must be from a normal distribution and exhibit insignificant auto correlation.
3. The monthly average emissions from the plant's primary control device, dry scrubbers, must be from a normal distribution and exhibit insignificant autocorrelation.

5.0 CONTROL CHART MONITORING

The control chart is the method proposed to monitor plant operating performance, especially during periods of reduced performance test frequency, to determine changes in plant operations which may affect emission levels. Control chart theory and its application to the ALUMAX aluminum plant data are the subject of this section. Limitations of the regulatory use of the performance test control charts will also be discussed, and a possible method to overcome those limitations is proposed.

5.1 CONTROL CHART THEORY

Knowledge of the behavior of chance variations is the foundation on which control-chart analysis rests. If a group of data is studied and its variation conforms to a statistical pattern that might reasonably be produced by chance causes, then it is assumed that no special assignable causes are present. The conditions which produce this variation are said to be "in control," or "under control." They are under control in the sense that, if chance causes alone are at work, then the amount and character of the variation may be predicted, and it is not possible to trace the variation of a specific instance to a particular cause. On the other hand, if the variations in the data do not conform to a pattern that might reasonably be produced by chance causes, then is is concluded that one or more assignable causes are at work. In this case, the conditions producing the variation are said to be "out of control."

An example of control charts is given in Figure 5-1. Set numbers given in the figure refer to sets of five machined product specimens each which were milled in two groups, Group I and Group II. Two control charts are shown, one for the average value, $\bar{X}$, of a critical dimension on the specimens for each set, and the other for their standard deviation, S. Central lines for each chart are shown as well as the upper control limits, UCL, and lower control limits, LCL. The upper and lower

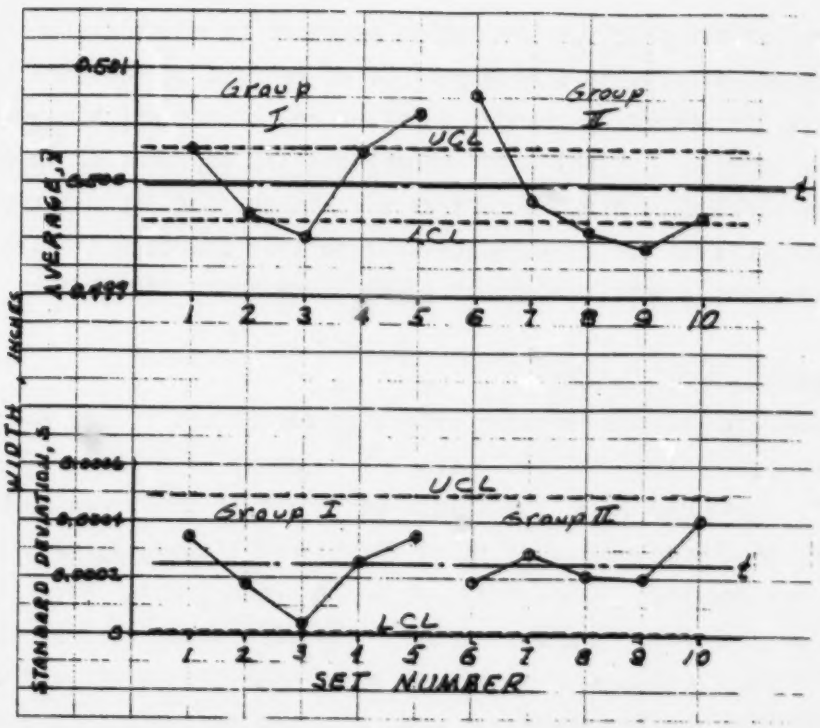


Figure 5-1. Control Charts for $\bar{X}$ and s

control limits are set at the 3-sigma limits above and below the central line, and are based on the variability of the specimens in each set number and on the number of specimens per set. If an average, $\bar{X}$, or standard deviation, S, falls outside the control limits, the milling process is out of control. Sets 3 and 5 for Group I, and Sets 6, 8, and 9 are seen to be outside the control limits, so the manufacturing process for Groups I and II are both out of control. In addition to the fact that the points fall outside the control limits on the $\bar{X}$ chart, the pattern of the averages for each group of sets does not exhibit random variation. For each group the averages begin high and then successively decrease to an out-of-control condition and then rise again. This pattern is a second indication of an out-of-control process. Examination of the S control chart for the same data groups, gives no indication that the standard deviation (the variability) is out-of-control. While the $\bar{X}$ control chart in this example shows an out-of-control condition, it does not indicate the cause of the condition. Persons familiar with the manufacturing process -- a milling process in this case -- would have to examine the entire procedure to make a judgement on an assignable cause for the condition.

An example of a control chart for a primary aluminum potroom group is given in Figure 5-2 for the ALUMAX Potroom Group containing Roof Monitor 101G and Dry Scrubber 161W. Figure 5-2 is the $\bar{X}$ chart for monthly mean emissions for the potroom group, plotted as a function of time. Each month, three measurements are taken and the average of those measurements is plotted on the figure. An S control chart, plotting the standard deviations of the three measurements each month versus time may also be prepared, but is not given here. The overall mean emission is plotted as the central line at about 0.849 lb F/T Al. Upper and lower control limits, UCL and LCL, respectively are plotted at 1.140 and 0.554 lb F/T Al. Figure 5-2 shows out-of-control points to have occurred in January 1981 and August 1982. The system recovered in each case by having the succeeding month's $\bar{X}$ fall within the control limits. Comparing Figures 5-1 and 5-2 emphasizes the random nature of the monthly mean emission which is clearly seen in the increasing and decreasing values of $\bar{X}$ in succeeding months as seen in Figure 5-2. There is one additional out-of-control criterion to be seen in Figure 5-2.

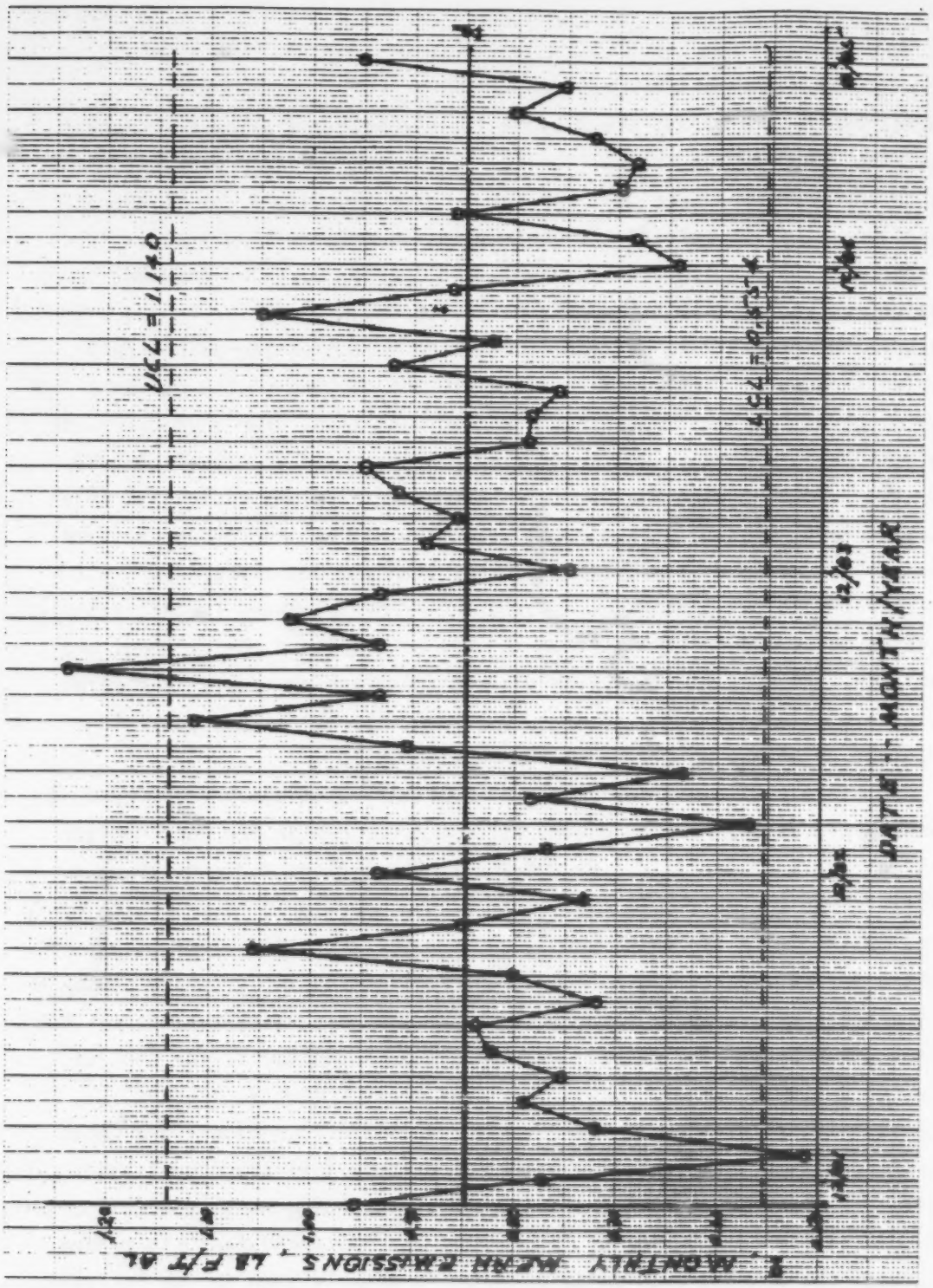


Figure 5-2. Monthly Mean Emissions for ALUMAX Potroom Group 101G/161W.

Nine consecutive points from December 1981 through August 1982 lie below the central line. Whenever seven or more points lie above or below the central line, an out-of-control condition exist for any control chart.

As indicated in the previous example, an out-of-control condition generally indicates that there is an assignable cause, or an identifiable reason, for the condition. No direct indication is given by the control chart what the reason is for the process' being out-of-control. The plant management and operating personnel will need to examine every step of the day-to-day operation to discover the assignable cause. Notice that the out-of-control condition in August 1983 indicated potroom group emissions about 1.24 lb F/T Al, still well below the emission limit of 1.9 lb F/T Al. Thus an out-of-control condition does not necessarily mean the potroom group is exceeding the emission limit.

The type of control chart described above is useful for monitoring the performance of a process to determine when the process is in control. For purposes of regulatory monitoring a process, especially during periods of reduced performance a second type of control chart, described below in Section 5.2, is ideally suited.

5.2 CONTROL CHART FOR REGULATORY USE

As described in more detail in Section 6, when a potroom group is petitioning for a reduced performance test schedule, it presents a history of emission performance for a period of at least 48 consecutive months of sampling. If the data analysis shows no autocorrelation, and the data are normally distributed then an overall mean, $\bar{\bar{X}}$, and the standard deviation of the monthly means, $S_{\bar{X}}$, and the standard deviation of the monthly means, $S_{\bar{\bar{X}}}$, are calculated to locate the potroom groups on Figure 4-1. Depending on the zone the potroom group is located in, the regulatory authority may qualify the potroom group for a less-frequent-than-monthly performance test schedule.

On the less frequent performance test schedule, e.g. annual frequency, the regulatory agency needs to be sure that if an overall change occurs in the emission level of the potroom group, that change is detected as soon as possible.

The control charts best suited for regulatory use are one in which there is control with respect to given standards, $\bar{\bar{X}}_0$ and σ_0. For the application of control of fluoride emissions from potroom groups, the standard used for the $\bar{X}$ chart is $\bar{\bar{X}}$, the overall monthly mean emission used to qualify the potroom group for the less frequent performance test schedule. For the S chart, the standard used is $\bar{S}_x$, the mean of the monthly standard deviations derived from the historical emissions data used to qualify the potroom group for the reduced sampling frequency. That is,

$$\bar{\bar{X}}_0 = \bar{\bar{X}}, \text{ and} \tag{5-1}$$

$$\sigma_0 = \bar{S}_x. \tag{5-2}$$

During the time the potroom group is on a reduced frequency sampling schedule, it is important to detect changes in operating levels as quickly as possible. Therefore, the operating levels used to qualify the potroom group for a less frequent performance test schedule are the standards against which change is to be measured. The same principles of control chart theory, insofar as the definition of control is concerned, apply to this second type of control chart as were indicated in Section 5.1 for the first type of control chart discussed.

Moreover, an additional restriction is recommended by this report for the $\bar{X}$ and S_x charts used in this application. Instead of using the 3-sigma control limits, UCL and LCL, suggested as appropriate for the control charts presented in Section 5.1, the 2-sigma warning limits, UWL and LWL, are recommended for the control charts used during the reduced performance test period. The 2-sigma limits lie closer to $\bar{\bar{X}}_0$ than the 3-sigma limits and thus provide an early warning indication of any change in the overall operating level. The 2-sigma warning limits are expected to be violated about one time in 20 performance tests, as a result of random variation alone; the 3-sigma control limits are expected to be violated about one time in 100 tests. Appendix B summarizes the methods used to calculate the upper and lower control limits and the upper and lower warning limits for control charts.

Section 5.3 derives the parameters needed for the ALUMAX control charts recommended here, and Section 5.4 illustrates the control chart use for regulatory purposes on a reduced sampling schedule.

5.3 ALUMAX CONTROL CHARTS

Emissions data for potroom groups of the Mount Holly plant of ALUMAX of South Carolina, provide the basis for control charts. These data are listed in Tables 5-1 through 5-4. Potroom Group 101G/161W was designated as the potroom group which contained Roof Monitor 101G and Dry Scrubber 161W. XBAR values in the table record the monthly mean emissions. For roof monitors the data were provided for each month from January 1981 (or March 1981) through August 1985.

For the dry scrubbers, monthly readings were given through about May 1985, and thereafter, only annually. For example, Table 5-1 shows values of XBAR for Dry Scrubber 161W derived from measured values from January 1981 through May 1982, then constant values of 0.0862 lb F/T Al are shown from June 1982 through August 1983. The value for September 1983 is derived from measured emission values. From October 1983 through September 1984, another constant value of 0.0889 is recorded. For October 1984, the value 0.0603 is the measured value for 1984, followed by the constant values of 0.0874 from November 1984 through August 1985. Consistent with regulatory requirements, measured monthly mean dry scrubber emission values were terminated after May 1982. Thereafter, only annual measurements were taken -- September for 1983 and October for 1984. For purposes of constructing the control charts for the potroom group emissions for the months for which dry scrubber readings were not taken, the overall dry scrubber average values up to that time were used.

Thus for the months from June 1982 through August 1983, 0.0862 was assumed to be the emission from Dry Scrubber 161W and was the calculated average emission for the data from January 1981 through May 1982. For the period from October 1983 through September 1984, 0.0889 was assumed to be the emission from Dry Scrubber 161W, and was the mean of dry scrubber emission data from January 1981 through May 1982 plus September 1983. Similarly, the value 0.0874 for the period from November 1984 through August 1985 was the mean of the measured Dry Scrubber 161W values from January 1981 through May 1982, plus September 1983 and October 1984.

Date	Roof Monitor 101-G XBAR	Dry Scrubber 161-W XBAR	Potroom Group 101G/161W XBAR	Roof Monitor 101-G STD DEV	Dry Scrubber 161-W STD DEV	Potroom Group 101G/161W VARIANCE	Potroom Group 101G/161W STD DEV
01/81	0.6053	0.0580	0.6633	0.1924	0.0485	0.03937001	0.19841
02/81	0.7167	0.0200	0.7367	0.0646	0.0017	0.00417605	0.06462
03/81	0.7370	0.0853	0.8223	0.0545	0.1037	0.01372394	0.11713
04/81	0.8010	0.0187	0.8197	0.2296	0.0032	0.05272640	0.22962
05/81	0.8473	0.1523	0.9996	0.1562	0.1887	0.06000613	0.24495
06/81	1.0200	0.2627	1.2827	0.1453	0.0931	0.02977970	0.17256
07/81	1.0100	0.0727	1.0827	0.0872	0.0337	0.00873953	0.09349
08/81	0.8267	0.0737	0.9004	0.0814	0.0064	0.00666692	0.08165
09/81	0.7267	0.0873	0.8140	0.0902	0.0186	0.00848200	0.09209
10/81	0.8867	0.0553	0.9420	0.0907	0.0274	0.00897725	0.09475
11/81	0.9060	0.0500	0.9560	0.1975	0.0107	0.03912074	0.19778
12/81	0.7320	0.0410	0.7730	0.2533	0.0053	0.06418898	0.25334
01/82	0.4393	0.0753	0.5146	0.1513	0.0192	0.02326033	0.15251
02/82	0.5170	0.2033	0.7203	0.0197	0.0604	0.00403625	0.06353
03/82	0.7700	0.0210	0.7910	0.2425	0.0026	0.05881301	0.24251
04/82	0.7033	0.0517	0.7550	0.0945	0.0110	0.00905125	0.09514
05/82	0.6867	0.1363	0.8230	0.0651	0.0667	0.00868690	0.09320
06/82	0.7467	0.0862	0.8329	0.1553	0.0634	0.02813765	0.16774
07/82	0.6333	0.0862	0.7195	0.1692	0.0634	0.03264820	0.18068
08/82	0.7167	0.0862	0.8029	0.1861	0.0634	0.03865277	0.19659
09/82	0.9700	0.0862	1.0562	0.1114	0.0634	0.01642952	0.12816
10/82	0.7667	0.0862	0.8529	0.1155	0.0634	0.01735981	0.13174
11/82	0.6467	0.0862	0.7329	0.1001	0.0634	0.01403957	0.11849
12/82	0.8500	0.0862	0.9362	0.1442	0.0634	0.02481320	0.15752
01/83	0.6833	0.0862	0.7695	0.1193	0.0634	0.01825205	0.13510
02/83	0.4833	0.0862	0.5695	0.0929	0.0634	0.01264997	0.11246
03/83	0.7000	0.0862	0.7862	0.1054	0.0634	0.01512872	0.12299
04/83	0.5500	0.0862	0.6362	0.1345	0.0634	0.02210981	0.14868
05/83	0.8200	0.0862	0.9062	0.0700	0.0634	0.00891956	0.09443
06/83	1.0300	0.0862	1.1162	0.2706	0.0634	0.07724392	0.27792
07/83	0.8467	0.0862	0.9329	0.0451	0.0634	0.00605357	0.07780
08/83	1.1533	0.0862	1.2395	0.1234	0.0634	0.01924712	0.13873
09/83	0.7967	0.1350	0.9317	0.1662	0.0780	0.03370644	0.18359
10/83	0.9533	0.0889	1.0422	0.3027	0.0643	0.09576178	0.30943
11/83	0.8433	0.0889	0.9322	0.1234	0.0643	0.01936205	0.13915
12/83	0.6600	0.0889	0.7489	0.3119	0.0643	0.10141610	0.31844
01/84	0.8000	0.0889	0.8889	0.0964	0.0643	0.01342745	0.11586
02/84	0.7700	0.0889	0.8589	0.1082	0.0643	0.01584173	0.12585
03/84	0.8267	0.0889	0.9156	0.1069	0.0643	0.01556210	0.12474
04/84	0.8600	0.0889	0.9489	0.1114	0.0643	0.01654445	0.12863
05/84	0.7000	0.0889	0.7889	0.1127	0.0643	0.01683578	0.12975
06/84	0.6967	0.0889	0.7856	0.0751	0.0643	0.00977450	0.09886
07/84	0.6700	0.0889	0.7589	0.1480	0.0643	0.02603849	0.16136
08/84	0.9033	0.0889	0.9922	0.3073	0.0643	0.09856778	0.31395
09/84	0.7333	0.0889	0.8222	0.1266	0.0643	0.02016205	0.14198
10/84	0.9900	0.0603	1.0503	0.0624	0.0117	0.00403065	0.06348
11/84	0.7767	0.0874	0.8641	0.0351	0.0627	0.00516330	0.07185
12/84	0.5367	0.0874	0.6241	0.0551	0.0627	0.00696730	0.08346
01/85	0.5967	0.0874	0.6841	0.1102	0.0627	0.01607533	0.12678
02/85	0.7733	0.0874	0.8607	0.2991	0.0627	0.09339210	0.30559
03/85	0.6100	0.0874	0.6974	0.0608	0.0627	0.00762793	0.08734
04/85	0.5967	0.0874	0.6841	0.1041	0.0627	0.01476810	0.12151
05/85	0.6367	0.0874	0.7241	0.2219	0.0627	0.05317090	0.23059
06/85	0.7167	0.0874	0.8041	0.1595	0.0627	0.02937154	0.17139
07/85	0.6650	0.0874	0.7524	0.0358	0.0627	0.00521293	0.07220
08/85	0.9203	0.0874	1.0077	0.0676	0.0627	0.00850105	0.09219
Average			0.8473				0.14990

TABLE 5-1. EMISSIONS DATA FOR ALUMAX POTROOM GROUP 101G/161W, LB F/T Al.

Date	Roof Monitor 101-H XBAR	Dry Scrubber 161-E XBAR	Potroom Group 101H/161E XBAR	Roof Monitor 101-H STD DEV	Dry Scrubber 161-E STD DEV	Potroom Group 101H/161E VARIANCE	Potroom Group 101H/161E STD DEV
01/81	0.6740	0.0200	0.6940	0.1216	0.0035	0.01479881	0.12165
02/81	1.2850	0.0350	1.3200	0.3234	0.0122	0.10473640	0.32361
03/81	0.8500	0.0173	0.8673	0.1036	0.0031	0.01074257	0.10364
04/81	0.9740	0.0333	1.0073	0.1785	0.0153	0.03209634	0.17915
05/81	0.7500	0.0820	0.8320	0.3219	0.0641	0.10772842	0.32821
06/81	1.1333	0.0737	1.2070	0.1601	0.0178	0.02594885	0.16108
07/81	0.8933	0.0623	0.9556	0.2223	0.0102	0.04952133	0.22252
08/81	0.6833	0.0810	0.7643	0.1069	0.0225	0.01193386	0.10924
09/81	0.8700	0.0703	0.9403	0.1808	0.0078	0.03274948	0.18095
10/81	0.9133	0.0417	0.9550	0.1115	0.0047	0.01245434	0.11160
11/81	0.8007	0.0367	0.8374	0.1398	0.0095	0.01963429	0.14011
12/81	0.8070	0.0697	0.8767	0.1236	0.0101	0.01537897	0.12400
01/82	0.5660	0.0187	0.5847	0.0666	0.0015	0.00443781	0.06661
02/82	1.0337	0.0397	1.0734	0.0199	0.0074	0.00045077	0.02123
03/82	0.9200	0.0150	0.9350	0.2778	0.0020	0.07717684	0.27781
04/82	0.8500	0.0303	0.8803	0.0436	0.0076	0.00195872	0.04425
05/82	0.7867	0.0430	0.8297	0.1222	0.0095	0.01502309	0.12256
06/82	0.7833	0.0453	0.8286	0.1582	0.0187	0.02537693	0.15929
07/82	0.8067	0.0453	0.8520	0.2098	0.0187	0.04436573	0.21064
08/82	0.8200	0.0453	0.8653	0.0265	0.0187	0.00105194	0.03243
09/82	1.1033	0.0453	1.1486	0.1168	0.0187	0.01399193	0.11828
10/82	0.9367	0.0453	0.9820	0.1380	0.0187	0.01939369	0.13924
11/82	0.7700	0.0453	0.8153	0.1323	0.0187	0.01785298	0.13361
12/82	0.8833	0.0453	0.9286	0.1357	0.0187	0.01876418	0.13696
01/83	0.7833	0.0453	0.8286	0.1350	0.0187	0.01857469	0.13628
02/83	0.8533	0.0453	0.8986	0.1401	0.0187	0.01997770	0.14133
03/83	0.7200	0.0453	0.7653	0.2931	0.0187	0.08625730	0.29369
04/83	0.6867	0.0453	0.7320	0.0950	0.0187	0.00937469	0.09682
05/83	0.9500	0.0453	0.9953	0.1908	0.0187	0.03675433	0.19170
06/83	0.9067	0.0453	0.9520	0.1115	0.0187	0.01278194	0.11305
07/83	0.9800	0.0453	1.0253	0.0520	0.0187	0.00305369	0.05526
08/83	1.0433	0.0453	1.0886	0.1850	0.0187	0.03457469	0.18594
09/83	0.8233	0.0537	0.8770	0.1102	0.0081	0.01220965	0.11049
10/83	0.8167	0.0457	0.8624	0.1537	0.0182	0.02395493	0.15477
11/83	0.8900	0.0457	0.9357	0.0624	0.0182	0.00422500	0.06500
12/83	0.8367	0.0457	0.8824	0.1041	0.0182	0.01116805	0.10568
01/84	0.8933	0.0457	0.9390	0.2003	0.0182	0.04045133	0.20113
02/84	0.8200	0.0457	0.8657	0.3260	0.0182	0.10660724	0.32650
03/84	0.8033	0.0457	0.8490	0.1429	0.0182	0.02075165	0.14404
04/84	0.8767	0.0457	0.9224	0.2970	0.0182	0.08854024	0.29757
05/84	0.7633	0.0457	0.8090	0.1701	0.0182	0.02926525	0.17108
06/84	0.8400	0.0457	0.8857	0.2338	0.0182	0.05499368	0.23452
07/84	0.7467	0.0457	0.7924	0.0569	0.0182	0.00356885	0.05974
08/84	1.0067	0.0457	1.0524	0.1060	0.0182	0.01156724	0.10754
09/84	0.7900	0.0457	0.8357	0.2718	0.0182	0.07420648	0.27242
10/84	0.9700	0.0570	1.0270	0.2600	0.0658	0.07192964	0.26817
11/84	1.0033	0.0463	1.0496	0.1518	0.0233	0.02358613	0.15356
12/84	0.9733	0.0463	1.0196	0.2775	0.0233	0.07754914	0.27848
01/85	1.0567	0.0463	1.1030	0.3252	0.0233	0.10629793	0.32601
02/85	0.7033	0.0463	0.7496	0.2710	0.0233	0.07398389	0.27201
03/85	0.8600	0.0463	0.9063	0.2651	0.0233	0.07082090	0.26612
04/85	0.7000	0.0463	0.7463	0.1311	0.0233	0.01773010	0.13314
05/85	1.0467	0.0463	1.0930	0.1595	0.0233	0.02598314	0.16118
06/85	0.9277	0.0463	0.9740	0.1300	0.0233	0.01744289	0.13207
07/85	1.0253	0.0874	1.1127	0.2400	0.0233	0.05814289	0.24113
08/85	0.7073	0.0463	0.7536	0.0405	0.0233	0.00218314	0.04672
Average			0.9162				0.16628

TABLE 5-2. EMISSIONS DATA FOR ALUMAX POTROOM GROUP 101H/161E, LB F/T Al.

Date	Roof Monitor 103-G XBAR	Dry Scrubber 162-W XBAR	Potroom Group 103G/162W XBAR	Roof Monitor 103-G STD DEV	Dry Scrubber 162-W STD DEV	Potroom Group 103G/162W VARIANCE	Potroom Group 103G/162W STD DEV
03/81	0.5430	0.0207	0.5637	0.0459	0.0045	0.00212706	0.04612
04/81	0.9405	0.0560	0.9965	0.0771	0.0390	0.00746541	0.08639
05/81	0.5933	0.0910	0.6843	0.2219	0.0148	0.04945865	0.22239
06/81	0.5800	0.1610	0.7410	0.0721	0.0746	0.01076357	0.10374
07/81	0.5800	0.0657	0.6457	0.0954	0.0163	0.00936685	0.09678
08/81	0.7067	0.0590	0.7657	0.2434	0.0098	0.05933960	0.24358
09/81	0.8620	0.0797	0.9417	0.1231	0.0204	0.01556977	0.12478
10/81	0.7590	0.1263	0.8853	0.1919	0.1058	0.04801925	0.21912
11/81	0.7953	0.0493	0.8446	0.0979	0.0059	0.00961922	0.09807
12/81	0.0280	0.0410	0.0690	0.0115	0.0053	0.00016034	0.01266
01/82	0.6323	0.1137	0.7460	0.1429	0.0359	0.02170922	0.14734
02/82	0.7483	0.0450	0.7933	0.2008	0.0066	0.04036420	0.20090
03/82	0.3333	0.0290	0.3623	0.0551	0.0060	0.00307201	0.05542
04/82	0.7500	0.0430	0.7930	0.0900	0.0166	0.00837556	0.09151
05/82	0.9200	0.0493	0.9693	0.0500	0.0093	0.00258649	0.05085
06/82	0.9000	0.0678	0.9678	0.4403	0.0376	0.19527785	0.44188
07/82	0.6567	0.0678	0.7245	0.0252	0.0376	0.00204880	0.04526
08/82	0.8100	0.0678	0.8778	0.1442	0.0376	0.02220740	0.14903
09/82	0.5033	0.0678	0.5711	0.0252	0.0376	0.00204880	0.04526
10/82	0.9067	0.0678	0.9745	0.3179	0.0376	0.10247417	0.32010
11/82	0.7333	0.0678	0.8011	0.0306	0.0376	0.00235012	0.04848
12/82	0.4967	0.0678	0.5645	0.1537	0.0376	0.02503745	0.15823
01/83	0.5367	0.0678	0.6045	0.2434	0.0376	0.06065732	0.24630
02/83	1.0033	0.0678	1.0711	0.2318	0.0376	0.05514500	0.23482
03/83	0.5633	0.0678	0.6311	0.0551	0.0376	0.00444977	0.06671
04/83	0.7067	0.0678	0.7745	0.0950	0.0376	0.01043876	0.10216
05/83	0.4333	0.0678	0.5011	0.0153	0.0376	0.00164785	0.04059
06/83	1.1200	0.0678	1.1878	0.0819	0.0376	0.00812137	0.09012
07/83	0.8433	0.0678	0.9111	0.1701	0.0376	0.03034777	0.17420
08/83	1.1167	0.0678	1.1845	0.2914	0.0376	0.08632772	0.29381
09/83	0.6000	0.0678	0.6678	0.1229	0.0376	0.01651817	0.12851
10/83	0.8000	0.0473	0.8473	0.0700	0.0123	0.00505129	0.07106
11/83	0.9300	0.0665	0.9965	0.0173	0.0365	0.00163154	0.04039
12/83	0.8867	0.0665	0.9532	0.1815	0.0365	0.03427450	0.18512
01/84	0.7300	0.0665	0.7965	0.1179	0.0365	0.01523266	0.12341
02/84	0.5500	0.0665	0.6165	0.0200	0.0365	0.00173225	0.04161
03/84	0.7033	0.0665	0.7698	0.0723	0.0365	0.00655954	0.08099
04/84	0.9267	0.0665	0.9932	0.1804	0.0365	0.03387641	0.18404
05/84	0.8167	0.0665	0.8832	0.1833	0.0365	0.03493114	0.18689
06/84	0.9533	0.0665	1.0198	0.0231	0.0365	0.00186586	0.04319
07/84	0.9533	0.0665	1.0198	0.1419	0.0365	0.02146786	0.14651
08/84	0.7300	0.0665	0.7965	0.0173	0.0365	0.00163154	0.04039
09/84	0.6667	0.0665	0.7332	0.0666	0.0365	0.00576781	0.07594
10/84	0.6033	0.0450	0.6483	0.1412	0.0161	0.02019665	0.14211
11/84	0.6633	0.0652	0.7285	0.1531	0.0356	0.02470697	0.15717
12/84	0.9800	0.0652	1.0452	0.0436	0.0356	0.00316832	0.05628
01/85	0.4100	0.0652	0.4752	0.1493	0.0356	0.02355785	0.15347
02/85	0.7167	0.0652	0.7819	0.1050	0.0356	0.01229236	0.11086
03/85	0.7300	0.0652	0.7952	0.1113	0.0356	0.01365505	0.11685
04/85	0.6367	0.0652	0.7019	0.2194	0.0356	0.04940372	0.22226
05/85	1.1300	0.0652	1.1952	0.0854	0.0356	0.00856052	0.09252
06/85	0.9067	0.0652	0.9719	0.0493	0.0356	0.00369785	0.06080
07/85	0.9410	0.0652	1.0062	0.0358	0.0356	0.00254900	0.05048
08/85	0.9237	0.0652	0.9889	0.0510	0.0356	0.00386836	0.06219
Average			0.8070				0.12647

TABLE 5-3. EMISSIONS DATA FOR ALUMAX POTROOM GROUP 103-G/162W, LB F/T Al.

Date	Roof Monitor 103-H XBAR	Dry Scrubber 162-E XBAR	Potroom Group 103H/162E XBAR	Roof Monitor 103-H STD DEV	Dry Scrubber 162-E STD DEV	Potroom Group 103H/162E VARIANCE	Potroom Group 103H/162E STD DEV
03/81	1.1287	0.0797	1.2084	0.1382	0.0649	0.02331125	0.15268
04/81	0.8043	0.0380	0.8423	0.1816	0.0040	0.03299456	0.18164
05/81	1.2900	0.1653	1.4553	0.1493	0.0352	0.02352953	0.15338
06/81	1.0867	0.1623	1.2490	0.0404	0.0470	0.00384116	0.06197
07/81	1.0567	0.1000	1.1567	0.0551	0.0078	0.00309685	0.05564
08/81	0.8400	0.2197	1.0597	0.0400	0.1424	0.02187776	0.14791
09/81	1.1057	0.1420	1.2477	0.2626	0.0985	0.07866101	0.28046
10/81	0.6680	0.1240	0.7920	0.0354	0.0201	0.00165717	0.04070
11/81	0.9750	0.1150	1.0900	0.1202	0.0229	0.01497245	0.12235
12/81	0.8937	0.0480	0.9417	0.2619	0.0030	0.06860061	0.26192
01/82	0.8230	0.0600	0.8830	0.2066	0.0092	0.04276820	0.20680
02/82	0.8710	0.1017	0.9727	0.2195	0.0341	0.04934306	0.22212
03/82	0.6033	0.0497	0.6530	0.1250	0.0092	0.01570964	0.12534
04/82	0.7733	0.0687	0.8420	0.0862	0.0127	0.00759173	0.08712
05/82	0.8967	0.1143	1.0110	0.1935	0.0327	0.03851154	0.19624
06/82	0.8700	0.1059	0.9759	0.1758	0.0524	0.03365140	0.18343
07/82	1.1833	0.1059	1.2892	0.2183	0.0524	0.05040065	0.22449
08/82	1.1167	0.1059	1.2226	0.2150	0.0524	0.04897076	0.22128
09/82	1.0200	0.1059	1.1259	0.1562	0.0524	0.02714420	0.16475
10/82	0.7100	0.1059	0.8159	0.1345	0.0524	0.02083601	0.14435
11/82	0.9033	0.1059	1.0092	0.2021	0.0524	0.04359017	0.20879
12/82	0.4200	0.1059	0.5259	0.1709	0.0524	0.03195257	0.17874
01/83	0.3700	0.1059	0.4759	0.1249	0.0524	0.01834577	0.13544
02/83	0.8700	0.1059	0.9759	0.1931	0.0524	0.04003337	0.20008
03/83	1.1067	0.1059	1.2126	0.5292	0.0524	0.28279840	0.53179
04/83	0.8200	0.1059	0.9259	0.0866	0.0524	0.01024532	0.10121
05/83	0.8933	0.1059	0.9992	0.1457	0.0524	0.02397425	0.15483
06/83	0.8600	0.1059	0.9659	0.0800	0.0524	0.00914576	0.09563
07/83	0.9733	0.1059	1.0792	0.1595	0.0524	0.02818601	0.16788
08/83	0.7500	0.1059	0.8559	0.0964	0.0524	0.01203872	0.10972
09/83	0.9067	0.1059	1.0126	0.0473	0.0524	0.00498305	0.07058
10/83	0.6867	0.0443	0.7310	0.1266	0.0047	0.01604965	0.12669
11/83	0.6667	0.1020	0.7687	0.0513	0.0508	0.00521233	0.07219
12/83	0.7700	0.1020	0.8720	0.1952	0.0508	0.04068368	0.20169
01/84	0.6900	0.1020	0.7920	0.1136	0.0508	0.01548560	0.12444
02/84	0.5967	0.1020	0.6987	0.1531	0.0508	0.02602025	0.16129
03/84	0.8633	0.1020	0.9653	0.2458	0.0508	0.06299828	0.25100
04/84	0.9700	0.1020	1.0720	0.3516	0.0508	0.12620320	0.35526
05/84	0.9167	0.1020	1.0187	0.1626	0.0508	0.02901940	0.17035
06/84	0.8233	0.1020	0.9253	0.1250	0.0508	0.01820564	0.13492
07/84	0.8867	0.1020	0.9887	0.0643	0.0508	0.00671513	0.08195
08/84	1.3133	0.1020	1.4153	0.1401	0.0508	0.02220865	0.14903
09/84	0.8700	0.0767	0.9467	0.1803	0.0290	0.03334909	0.18261
10/84	0.7467	0.1006	0.8473	0.2060	0.0498	0.04491604	0.21192
11/84	0.8233	0.1006	0.9239	0.1739	0.0498	0.03272125	0.18088
12/84	0.7067	0.1006	0.8073	0.1210	0.0498	0.01712104	0.13085
01/85	0.4200	0.1006	0.5206	0.0794	0.0498	0.00878440	0.09372
02/85	0.6367	0.1006	0.7373	0.0902	0.0498	0.01061608	0.10303
03/85	0.9300	0.1006	1.0306	0.1819	0.0498	0.03556765	0.18858
04/85	0.7933	0.1006	0.8939	0.0833	0.0498	0.00941893	0.09705
05/85	0.9033	0.1006	1.0039	0.1767	0.0498	0.03370293	0.18358
06/85	0.9520	0.1006	1.0526	0.1911	0.0498	0.03899925	0.19748
07/85	0.9345	0.1006	1.0351	0.2072	0.0498	0.04541188	0.21309
08/85	0.9217	0.1006	1.0223	0.1045	0.0498	0.01340029	0.11576
Average			0.9618				0.16512

TABLE 5-4. EMISSIONS DATA FOR ALUMAX POTROOM GROUP 103H/162E, LB F/T Al.

As indicated in the model proposed in Section 4, the monthly mean potroom group emissions, $\bar{X}$, equal the sum of the roof monitor emissions $\bar{X}$, and the dry scrubber emissions. That is:

$$\bar{X} = \bar{X}_1 + \bar{X}_2 \tag{5-1}$$

Similar procedures were employed to estimate the monthly standard deviations of the dry scrubbers for those months for which performance tests were not conducted. In this case, however, variances were averaged, from which standard deviations were calculated. For example, the standard deviation, 0.0634, used for the period from June 1982 through August 1983, was calculated from the mean variance calculated for the months from January 1981 through May 1982. That is:

$$S_{6/82} = [(S^2_{1/81} + S^2_{2/81} + S^2_{3/81} + \ldots + S^2_{4/82} + S^2_{5/82})/17]^{1/2}, \tag{5-2}$$

$$S_{6/82\text{-}8/83} = 0.0634 = [(0.0435^2 + 0.0017^2 + 0.1037^2 + 0.0032^2 + \ldots + 0.0110^2 + 0.00672)/17]^{1/2}. \tag{5-3}$$

For the period from October 1983 through September 1984:

$$S_{10/83\text{-}9/84} = [(S^2_{1/81} + S^2_{2/81} + S^2_{3/81} + \ldots + S^2_{5/82} + S^2_{9/83})/18]^{1/2}$$

$$S_{10/83\text{-}9/84} = 0.0643 \text{ lb F/T Al.} \tag{5-4}$$

From November 1984 through August 1985:

$$S_{11/84\text{-}9/84} = [(S^2_{1/81} + S^2_{2/81} + S^2_{3/81} + \ldots + S^2_{5/82} + S^2_{9/83} + S^2_{10/84})/19]^{1/2}. \tag{5-5}$$

As also indicated in Section 4.0, the standard deviation of the potroom group is calculated from the variances of the roof monitor and the dry scrubber monthly readings, as follows:

$$S^2_i = S^2_{1i} + S^2_{2i}, \tag{5-6}$$

Where S^2_i = the potroom group monthly variance estimate for month i,

S^2_{1i} = the roof monitor monthly variance estimate for month i, and

S^2_{2i} = the dry scrubber monthly variance estimate for month i.

For example for January 1981, it can be seen from the first row of numerals in Table 5-1,

$$S^2_{1i} = (0.1924)^2, \quad (5\text{-}7)$$

$$S^2_{2i} = (0.0485)^2, \text{ and} \quad (5\text{-}8)$$

$$S^2_{1/81} = 0.03937001, \text{ or} \quad (5\text{-}9)$$

$$S_{1/81} = 0.1984 \text{ lb F/T Al}. \quad (5\text{-}10)$$

The monthly mean value of standard deviations, $\bar{S}_x$, is seen from Table 5-1 to be 0.1499 lb F/T Al, while the overall monthly means from the potroom group, $\bar{\bar{X}}$, is 0.8473 lb F/T Al. $\bar{\bar{X}}$ and $\bar{S}_x$ for the other ALUMAX potroom groups are given in Tables 5-4 through 5-6.

Table 5-5 shows the results of the calculation of the upper and lower warning limits. Details of the calculations are given in Appendix B, and are based on the methods used by the ASTM[10]. Figures 5-3 and 5-4 show the $\bar{X}$ and S_x control charts for ALUMAX Potroom Group 101G/161W, including Roof Monitor 101G and Dry Scrubber 161W. Control charts for the other ALUMAX potroom group are not included, but will be similar to Figure 5-4 and 5-5, using the data of Table 5-5 for their construction.

5.4 DERIVATION OF ALUMAX CONTROL CHARTS

A control chart would be required for $\bar{X}$ and S_x for each potroom group. Thus for the ALUMAX plant, eight control charts would be needed, two for each potroom. Each month for which sampling is done, the monthly mean $\bar{X}_i$, and the standard deviation of the three daily readings, S_{xi} are calculated.

TABLE 5-5. POTROOM GROUP WARNING LIMITS, ALUMAX DATA

Potroom Group	$\bar{X}$ Chart[a]			S_x Chart[a]		
	Central Line, $\bar{X}_o$	UWL	LWL	Central Line, σ_o[c]	UWL	LWL
101G/161W	0.8473	1.043	0.652	0.1499	0.272	0
101H/161E	0.9162	1.133	0.700	0.1663	0.302	0
103G/162W	0.8070	0.972	0.642	0.1265	0.229	0
103H/162E	0.9618	1.177	0.747	0.1651	0.299	0

[a]Limits are based on a monthly sample size of 3, i.e., three daily readings per month to calculate $\bar{X}_i$ and s_{xi}.

[b]Standard central line, $\bar{X}_o = \bar{\bar{X}}$, overall mean of monthly means for ALUMAX data.

[c]Standard Deviation, $\sigma_o = \bar{s}_x$ for ALUMAX data.

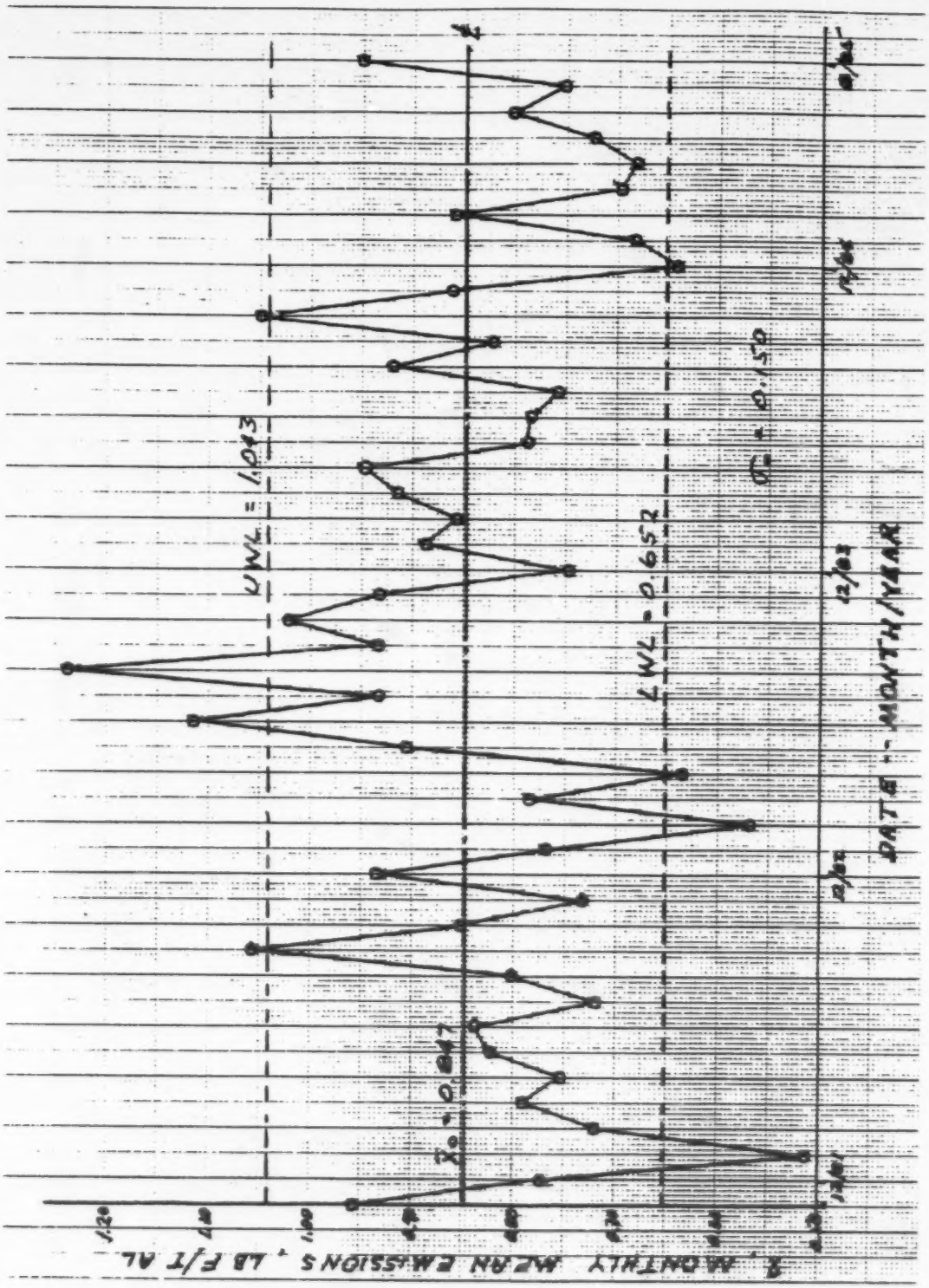


Figure 5-3. $\bar{X}$ Control Chart for ALUMAX Potroom Groups 101G/161W, with Respect to Standards $\bar{X}_0$ and σ_0.

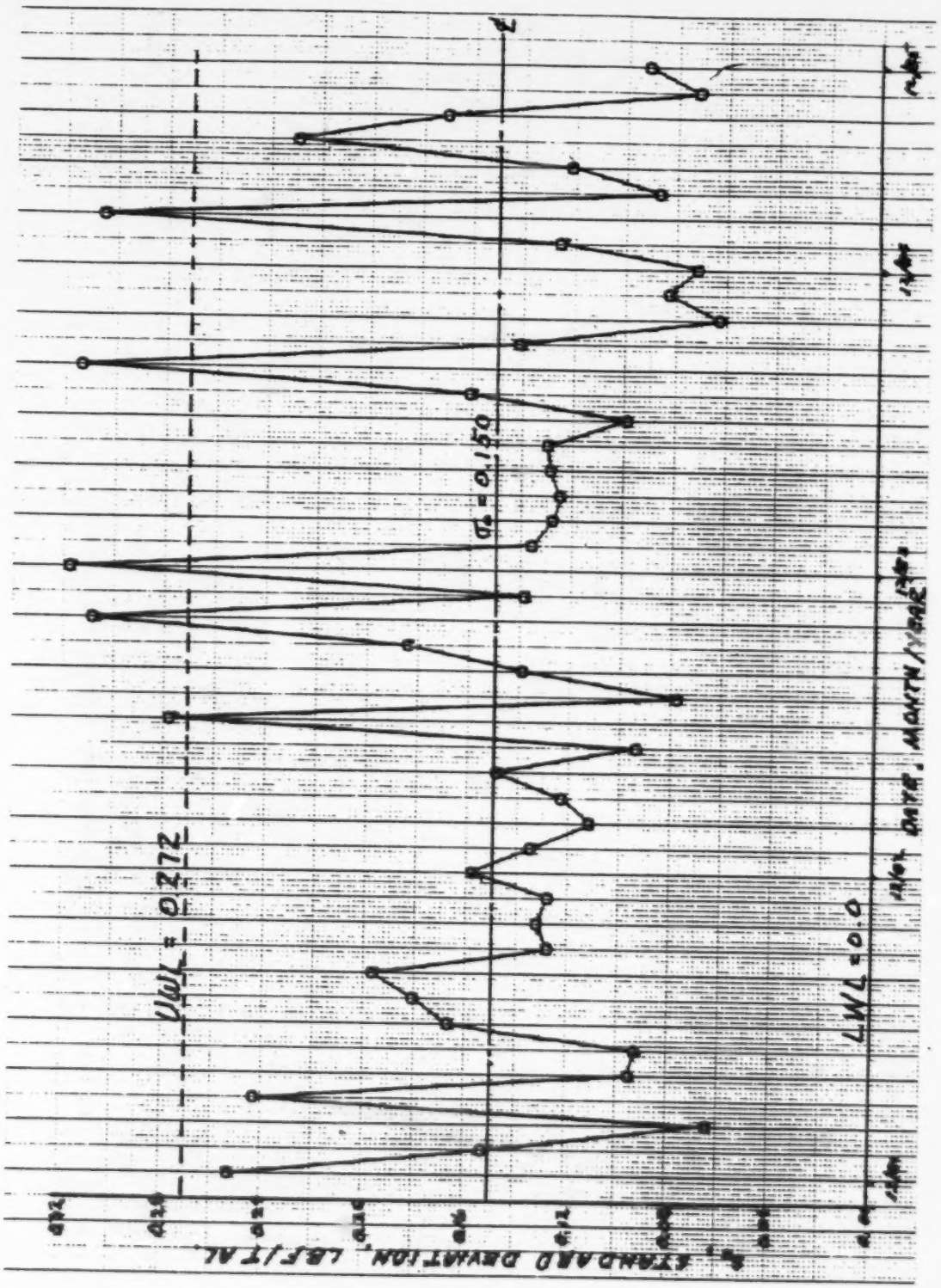


Figure 5-4. S_X Control Chart For ALUMAX Potroom Group 101G/161W, with respect to Standards $\bar{X}_o$ and σ_o.

Their values could either be plotted on the $\bar{X}$ and S_x chart or numerically compared with the UWL and LWL values in Table 5-7. If LWL < $\bar{X}_i$ < UWL for the $\bar{X}$ chart, and if LWL < S_{xi} < UWL for the S chart, then the process is in control. Graphically, if X_i and S_{xi} fall between UWL and LWL, the indications are the process is in control. Should any of the inequalities cited above not be true, i.e., should $\bar{X}_i$ or S_{xi} fall outside the warning limits, then action is appropriate. An example of regulatory actions that might be taken is given in the next section.

5.5 REGULATORY USE OF ALUMAX CONTROL CHARTS

The regulatory action taken if the monthly $\bar{X}_i$ and S_{xi} fall outside the warning limits should relate to the risk involved. For example, the risk of an exceedance, or the risk of any process change (or emission change) going undetected, is inversely proportional to the frequency of performance testing. A yearly schedule of performance testing results in a higher risk of an undetected emission level change than a quarterly schedule of testing.

The example that follows assumes an annual performance test schedule. It uses corrective action having stringent requirements and guidelines. This was intentionally done to err on the side of being overly cautious so as not to permit any potential change in overall emission level to be unchallenged and unverified. As the regulatory procedure gains more experience, then the periodic review of the procedures that are recommended, might relax some of the requirements of quarterly performance test schedule compared to the requirements of an annual schedule. Such a relaxation would be consistent with the fact that the risk of an undetermined change on a quarterly performance test schedule is less than the risk for an annual schedule.

The most important control chart criterion to monitor, from the regulatory standpoint, is the Upper Warning Limit, UWL, on the $\bar{X}$ control chart. If the overall emission level of the potroom group is increasing, the most likely indication would be the violation of the UWL on the $\bar{X}$ control chart. Showed $\bar{X}_i$ for any month be greater than UWL on the $\bar{X}$ chart,

additional action must be taken immediately to determine if the violation is caused by random variation, or by an overall increase in emission levels greater than $\bar{X}_o$. The method for making this judgement is given in the example below.

On the otherhand, if $\bar{X}_i$ is less than LWL on the $\bar{X}$ chart, or if a monthly standard deviation, S_{xi} lies outside the warning limits of the S_x chart, then that occurrence too should be treated as a potential change in maintenance or operational practice which may indicate a change in emissions. Unexpectedly low levels of $\bar{X}_i$, e.g., below LWL, may indicate a sampling problem which is giving a falsely low measurement.

Values of S_{xi} greater than UWL on the S_x chart may indicate a larger-than-expected daily fluctuation in the fluoride emissions, or it may indicate a careless analytical technique, or even an error in the calculation of the results. Similarly, lower-than-usual values of S_{xi} may indicate invalid sampling or analysis techniques. In short, any violations of the warning limits on the $\bar{X}$ chart or the S_x chart should be investigated as a potential change in operating or maintenance procedures in the potroom group.

In the discussion that follows, the logic of the regulatory actions will be outlined as briefly as possible. The mathematical formulas on which the logic and the decisions are based are given in detail in Appendix C, HYPOTHESIS TESTING.

To give an example of the regulatory action that may be taken, the following set of conditions are assumed:

1. Potroom Group 101G/161W has requested an annual performance test schedule based on their previous performance schedule of 3 samples per month and 56 months of testing.
2. Potroom Group 101G/161W is permitted to go on an annual sampling and performance test schedule based on the location of the potroom group in Figure 4-1 and $\bar{\bar{X}} = 0.8473$, and $S_{\bar{x}} = 0.1520$ lb F/T Al.
3. Warning Limits and Central Lines in units of lb F/T Al have been established as follows:

	Warning Limits		Central Lines	
	UWL	LWL	$\bar{X}_o$	σ
$\bar{X}$ chart	1.043	0.652	0.847	---
S_x chart	0.302	0.000	---	0.1499

So long as the potroom group can demonstrate control, annual sampling and performance tests can continue. To demonstrate control, both the annual means (of three consecutive daily readings) $\bar{X}_i$ and the standard deviations of the three readings, S_{xi} must fall within the established warning limits. That is, an exceedance or violation of the control limits occurs when any of the following inequalities is untrue.

$$0.652 < \bar{X}_i < 1.043, \text{ and}$$
$$0.0 < S_{xi} < 0.302.$$

If any one of the four limits is violated, certain actions are required. From the regulatory standpoint, the most critical limit is the upper warning limit on $\bar{X}_i$, 1.043. If $\bar{X}_i \geq 1.043$, the overall level of emissions for the potroom group may have increased, which may invalidate the basis for granting a reduced sampling schedule.

The discussion that follows focuses on $\bar{X}_i$. Discussions on S_x follow the discussion dealing with $\bar{X}i$ exceedances of the control limits.

1. Let $\bar{X}$ be the first annual mean potroom group emission rate, lb F/T Al that gives $\bar{X}_i > 1.043$.
2. Whenever $\bar{X}_i \geq 1.043$, the potroom group will be required to sample the following month, calling the mean for the following month $\bar{X}_2$.
3. After $\bar{X}_2$ has been determined, three possibilities exist.
   a. $\bar{X}_2 \geq 1.043$
   b. $\bar{X}_2 < 1.043$, but $[(\bar{X}_1 + \bar{X}_2)/2] < 1.043$
   c. $\bar{X}_2 < 1.043$, but $[(\bar{X}_1 + \bar{X}_2)/2] > 1.043$
4. If 3(a) occurs, then the potroom group is required to do performance tests monthly for the next six months, determining $\bar{X}_3$, $\bar{X}_4$, $\bar{X}_5$, $\bar{X}_6$, $\bar{X}_7$, and $\bar{X}_8$.

5. If 3(b) occurs, the potroom group may return to annual sampling and performance tests.
6. If 3(c) occurs, sampling will be required a third month consecutively giving $\bar{X}_3$.
7. Three possibilities exist, after sampling the third consecutive month,
   a. $\bar{X}_3 \geq 1.043$
   b. $\bar{X}_3 < 1.043$ and $[(\bar{X}_1 + \bar{X}_2 + \bar{X}_3)/3] < 1.043$, or
   c. $\bar{X}_3 < 1.043$ and $[(\bar{X}_1 + \bar{X}_2 + \bar{X}_3)/3] > 1.043$
8. If 7(a) occurs, then sampling will be required for the next 5 months, giving $\bar{X}_4$, $\bar{X}_5$, $\bar{X}_6$, $\bar{X}_7$, and $\bar{X}_8$.
9. If 7(b) occurs, then the potroom group may return to an Annual sampling schedule.
10. If 7(c) occurs, then sampling will be required for the next 5 months, giving $\bar{X}_4$, $\bar{X}_5$, $\bar{X}_6$, $\bar{X}_7$, and $\bar{X}_8$.
11. If 3(a), 7(a), or 7(c) occurs, a total of 8 months of consecutive testing will have accurred. Based on these eight months of testing, a reevaluation of the overall operating level, i.e., the 8-month mean, will be done to decide whether the 8-month mean is significantly larger than the initial mean, $\bar{X}_0$, upon which the reduced performance test is based. The decision will be based on the outcome of an hypothesis test on the means (X_0 and the 8-month mean, $\bar{X}$,) described in Appendix C.
12. If the hypothesis test indicates that no change has occurred in the emissions level, then the potroom group may return to annual sampling.
13. If the hypothesis test causes the decision to be made that an increased emissions level has occurred, then a reevaluation of whether the potroom group still qualifies for reduced sampling schedule by relocating $\bar{\bar{X}}_1$ and $S_{\bar{x}1}$ on Figure 4-1 and see if the potroom group still qualifies for reduced sampling.
14. If the potroom group no longer qualifies for annual sampling, then it must return to the appropriate sampling and analysis schedule as determined by the regulatory agency, e.g., see Table 2-1.

15. If the potroom group still qualifies for annual sampling according to the guidelines set by the Regulatory Authority in Figure 4-1, then new values of $\bar{X}_0$, σ_0, and UWL and LWL for the $\bar{X}$ and S_x charts must be calculated based on the most recent 8-month performance test results.
16. Should a subsequent annual reading be greater than the new UWL, return to Step 1 and follow Steps 2 through 16, as indicated.

Should $\bar{X}_i$ be less than the Lower Warning Limit (i.e., $\bar{X}_i < 0.652$), no regulatory action may be required. Low values of $\bar{X}_i$ may result from (a) normal random variation, (b) improved emission control operating procedures, or (c) inaccurate or incorrect analytical results. If (a) or (b) is the cause of $\bar{X}_i < 0.652$, then no regulatory action is needed. If, however, the cause of $\bar{X}_i < 0.652$ is (c), inaccurate or incorrect analytical performance test results, then corrective measures may be indicated.

A regulatory scenario for the latter case might follow the pattern outlined below:

1. If $\bar{X}_i < 0.652$ for two consecutive years (i.e., $\bar{X}_1$ and $\bar{X}_2 < 0.652$), examine sampling and analysis procedures carefully. Check all the analytical equipment for leaks. Check all calculations for an error. Recalibrate the instruments.
2. If $\bar{X}_i < 0.652$ for three consecutive years (i.e., $\bar{X}_1$, $\bar{X}_2$, and $\bar{X}_3 < 0.652$), return to monthly sampling for the next five months, obtaining $\bar{X}_4$, $\bar{X}_5$, $\bar{X}_6$, $\bar{X}_7$, and $\bar{X}_8$; and S_{x4}, S_{x5}, S_{x6}, S_{x7}, and S_{x8}.
3. Test the hypothesis that the true mean of the last eight determinations, $\bar{X}_1$, $\bar{X}_2$, ... , $\bar{X}_8$ is less than the true mean of the original 56-monthly means, using the appropriate Test of Hypothesis given in Appendix C.
4. If the test indicates that the overall emissions level has decreased, recalculate $\bar{X}_0$, $\bar{S}_x$, UWL and LWL for the $\bar{X}$ chart and the S_x chart using the most recent eight determinations of $\bar{X}_i$ and S_{xi}. Return to annual samples using the new control chart parameters just calculated.

5. If five consecutive annual readings fall below the central line, $\bar{X}o$, (and at the same time greater than LWL) the action items of Step 1 should be done:
   - check all analytical instruments for leaks,
   - check all calculations for error, and
   - Recalibrate the instruments before the next performance test.
6. If six consecutive annual readings fall below the central line (and at the same time greater than LWL), $\bar{X}o$ return to monthly sampling for the next 5 months, obtaining $\bar{X}_4$, $\bar{X}_5$, $\bar{X}_7$, and $\bar{X}_8$ (also the corresponding standard deviations).
7. Proceed as in Steps 3 and 4.

The probability of a run of five to six values of $\bar{X}_i$ less than the central value on the $\bar{X}$ chart is very small, but the possibility cannot be discounted completely or ignored.

For the S_X control chart, there is no possibility of having less than $S_{xi}=0.0$, since S_{xi} is defined as the positive root of $\left(\sum_i (X_i - \bar{X})^2/(n-1)\right)^{1/2}$. If S_{xi} > UWL (=0.302 for the example used here), there is an obvious instability in the daily emissions measurements for the given month. The instability may be occurring because of (a) random variation; (b) change in operating procedures causing highly variable emissions measurements; (c) change in sampling and analysis precision, perhaps faulty equipment; or (d) an error in the calculation of results. If the problem results from (a) or (d), the only response needed is to correct any known error. Should (b) or (c) be the cause of S_{xi} > 0.302, corrective measures should focus on answering the question, "What change in sampling analysis, or operating, procedures have occurred?", and taking the appropriate steps to correct the problem.

A reasonable regulatory course of action for the standard deviation readings, similar to that used for $\bar{X}_i$, is outlined below:

1. Let S_{x1} be the first annual standard deviation of the three daily measurements in a given month that exceeds UWL.

2. If $S_{x1} > 0.302$, then the potroom group will be required to do a performance test the next month.
3. After S_{x2} has been determined, three possibilities exist:
   (a) $S_{x2} > 0.302$,
   (b) $S_{x2} < 0.302$, but $[(S_{x1} + S_{x2})/2] > 0.302$, and
   (c) $S_{x2} < 0.302$, but $[(S_{x1} + S_{x2})/2] < 0.302$.
4. If 3(a) or 3(b) occurs, the potroom group should continue monthly performance tests for the next six months, determining S_{x3}, S_{x4}, S_{x5}, S_{x6}, S_{x7}, and S_{x8}. Proceed to Step 6.
5. If 3(c) occurs, the potroom group may return to annual sampling.
6. Redetermine $\bar{X}$ for the latest eight readings. Test the hypothesis that the true mean of the last 8 is greater than the true mean of the original 56 data points (Appendix C).
7. If the test indicates that $\bar{X}$ for the last eight data has increased, then recalculate $\bar{\bar{X}}$ and $S_{\bar{x}}$ and recheck the eligibility of the potroom group for annual sampling from Figure 4-1.
8. If the potroom group using the new $\bar{\bar{X}}$ and $S_{\bar{x}}$ qualifies for annual sampling, recalculate X_0, σ_0, UWL, and LWL for the potroom group and return to annual sampling using the revised control chart parameters.
9. If the test given in Step 6 indicates that no change has occurred in the overall monthly mean emissions, then return to annual sampling using the original control chart parameters.
10. If the potroom group using the new $\bar{\bar{X}}$ and $S_{\bar{x}}$ does not qualify (in Step 8) for annual sampling, then it shall return to the appropriate sampling and per performance test schedule based on Figure 4-1 and Table 2-1.

Should $\bar{X}_i$ and S_{xi} exceed their respective limits simultaneously, the procedures outlined for the $\bar{X}$ parameters should take precedence.

5.6 LIMITATIONS OF REGULATORY USE OF CONTROL CHART

The basic assumption of control chart theory is that the sampling interval is frequent enough to characterize the process, and that little

process change occurs between sampling periods. Currently, the NSPS for primary aluminum plants requires monthly performance testing. A reduced performance test schedule could be set for quarterly sampling, semi-annual, annual, or other sampling intervals. The longer interval between performance tests, the slower would be the detectable response to any systematic or overall change in emission levels and the lower the level of assurance that changes in emissions performance are detected by the reduced monitoring frequency. Furthermore, during periods between performance tests the regulatory authority must take on faith that plant operations and emission rates remain constant. The presumption that plant operations remain constant between tests is the basic limitation of the $\bar{X}$ and S_x control chart procedure for sanctioning reduced monitoring frequency.

Control chart theory, however, can be applied again in a different manner to offset this limitation and help ensure compliance with the NSPS. The premise is to track and chart parameters other than the performance test data during the periods between tests as a surrogate monitoring method. Fortunately, various routine maintenance procedures and operational practices done by primary aluminum plant personnel are ongoing and occur on each shift, daily, or on some other regular periodic interval. Listed below are some routine procedures and daily occurrences that can be related to the plant operating performance and to the fluoride emissions.

- The number of loose vent covers on the aluminum cell housings each day;
- The number of bent vent covers;
- The number of gaskets changed per day (or per week);
- The number of cells showing buildup of electrolytic cell minerals on the top edge of cell;
- The number of locations per day requiring clean up of electrolyte cell materials from the potroom floor;
- The pounds of electrolyte spilled and swept up from the floor per day; and
- The time it takes to change each anode.
- The number of days required between baghouse filter replacement.

Some of these are measurable parameters that could be "monitored" between performance tests.

There are many other daily routine tasks not listed above that need to be done to keep the plant operating efficiently and "in control." Documentation and quantification of a defined set of these tasks during the period of monthly sampling would permit the construction of a control chart that would relate to operating and maintenance performance of the plant.

When the potroom group qualifies for reduced performance test scheduling, the operating/maintenance control chart would continue to be maintained on the same periodic schedule it operated on before the potroom group qualified for reduced performance testing. Any change in the operating performance would be detected in this control chart, and could signal a possible out-of-control condition which affects the emissions level. The operating/maintenance control chart could serve as a surrogate performance monitoring tool, and with experience and the appropriate data could be related to flupride emission rates (lb F/T Al). Out-of-control conditions with the operating/maintenance control charts would trigger an increased performance test frequency in much the same way as did the $\bar{X}$ and $S_{\bar{X}}$ control charts described in the previous section.

The specific operating/maintenance parameters to be monitored would be determined by evaluating plant operations on a case-by-case basis. The concept, however, is described here for those regulatory authorities that would require assurance that plant operations have not changed between test periods.

6.0 REGULATORY PROCEDURES

This section outlines the steps that are recommended and the data that are required to qualify a potroom group in a primary aluminum plant for a reduced frequency performance test schedule. Quantitative criteria are offered for making the decision as to which potroom groups are qualified for a reduced frequency performance test schedule, and what the frequency of testing should be. Suggestions are given for regulatory procedures while the potroom group is on a reduced frequency performance test schedule.

Step 1. Assemble at least four years of consecutive monthly results of emission rates, lb F/T Al, from roof monitors in potroom groups. Four years of dry scrubber emission rates are also needed, on whatever periodic schedules have been specified by the appropriate regulatory agency. It is assumed that each monthly performance test measurement on the roof monitor or dry scrubber includes three separate daily measurements from which the monthly means and standard deviations may be determined.

Step 2. Determine if there is a significant covariance of the roof monitor and dry scrubber emissions. If the covariance is insignificant, Equation 4-2 may be used to determine the monthly standard deviation for the potroom group, otherwise a covariance term must be added as in Equation 3-2. Equation 4-1 may be used to determine the monthly mean emissions for the potroom group.

Step 3. Determine if the potroom group monthly mean emissions are autocorrelated. If they are not significantly autocorrelated, Figure 4-1 and a table such as Table 6-1, may be used to qualify the potroom group for a reduced schedule performance test. If there is significant autocorrelation a new Probability-of-an-Exceedance graph must be derived.

TABLE 6-1. EXAMPLE CRITERIA FOR REDUCED PERFORMANCE TEST SCHEDULE

Probability of an Exceedance, P	Example Performance Test Schedule[a]
$P > 0.001$	one/month
$0.0001 < P < 0.001$[b]	one/quarter
$0.00001 \quad P < 0.0001$[c]	one/6 months
$P < 0.00001$	one/12 months

[a] Selection of the performance test schedule is the preview of the regulatory authority.

[b] $P = 0.001$ means that one exceedance would be expected with every 1,000 measurements or about 83.3 years, on the original monthly performance test schedule assuming only random variation.

[c] $P = 0.0001$ means that one exceedance would be expected with every 10,000 measurements, or about every 833.33 years, on the original monthly performance test schedule.

Step 4. Determine the overall monthly mean and monthly standard deviation for the potroom group for the entire time period available in Step 1.

Step 5. Determine the frequency distribution of the roof monitor data. If the frequency distribution is normally distributed, and there is no significant autocorrelation to the data, the Probability-of-an-Exceedance graph (Figure 4-1) developed for this study may be used; otherwise a new Probability-of-an-Exceedance graph must be developed.

Step 6. Determine probability of an exceedance from Figure 4-1. This assumes that they are normally distributed random variables.

Step 7. Regulatory authority selects appropriate performance test schedule from Probability of Exceedance for potroom group determined in Step 6. Example criteria for a reduced performance test schedule are given in Table 6-1.

Step 8. Construct performance test $\bar{X}$ and S_x control charts and follow a monitoring protocol determined by the regulatory authority. A protocol for monitoring control charts on a reduced performance test schedule is suggested in Section 6.

Step 9. Construct surrogate parameter $\bar{X}$ and S_x control chart to monitor operating performance while on reduced performance test schedule. The surrogate parameter is a routine measurement or housekeeping procedure that is done routinely by operating personnel whether or not the potroom groups is on reduced performance test schedule. See Section 2 for the details.

7.0 REFERENCES

1. "Four Year Statistical Analysis," ALUMAX of South Carolina (1985).

2. Daniels, M., ALUMAX of South Carolina, letter to Robert McCalister [sic], dated September 19, 1985.

3. Steel, Robert G.D. and James H. Torrie, "Principles and Procedures of Statistics," 2nd. ed. McGraw-Hill Book Company. New York (1979).

4. Pankratz, A., "Forecasting With Univariate Box - Jenkins Models. Concepts and Cases," John Wiley & Sons, New York (1983).

5. Tukey, John W., "Exploratory Data Analysis," Addison-Wesley Publishing Company, Reading, MA (1977).

6. Charavarti, I.M., R.G. Laha, and J. Roy, "Handbook of Methods of Applied Statistics, Volume I. Techniques of Computation, Descriptive Methods, and Statistical Inference," John Wiley & Sons, Inc., New York (1967).

7. Anderson, T.W., "The Statistical Analysis of Time Series," John Wiley & Sons, New York (1971).

8. Hald, A., "Statistical Tables and Formulas," John Wiley & Sons, Inc., London (1952).

9. Aitchison, J., and J.A.C. Brown, "The Lognormal Distribution," Cambridge University Press, Cambridge (1957).

10. "ASTM Manual on Presentation of Data and Control Chart Analysis," ASTM Special Technical Publication 15D., American Society for Testing and Materials, Philadelphia, PA 19103 (1976).

11. Duncan, Acheson J., "Quality Control and Industrial Statistics," 3rd Edition, Richard D. Irwin, Inc., Homewood, Illinois (1965).

12. Hastings, N.A.J., and J.B. Peacock, "Statistical Distributions," John Wiley & Sons, New York (1975).

13. Hald, A., "Statistical Theory with Engineering Applications," John Wiley & Sons, Inc., New York (1952).

14. Snedecor, George W., and William G. Cochran, "Statistical Methods," 7th ed., The Iowa State University Press, Ames. (1980).

15. SAS® Institute, Inc., "SAS/ETS® User's Guide," Version 5 Edition, Cary, NC: SAS® Institute, Inc. (1984).

16. Letter from R. C. Dickie, ALUMAX, to Jack R. Farmer, U. S. EPA, August 27, 1985, Attachment entitled "Emission Test Results, Potline 1 & 2, October 1984.

17. Letter from Hurtis L. Givens, Alcan Aluminum to Eric Noble, U. S. EPA, undated (received 6/28/85). Attachment entitled "Potline Roof Emissions, Total Fluorides."

18. Letter from Hurtis L. Givens, Alcan Aluminum to Eric Noble, U. S. EPA, undated (received 11/20/85). Attachment entitled "NSPS Total F Emissions Data."

19. Letter from Robert E. Hurt, Noranda Aluminum to Eric Noble, U. S. EPA, August 14, 1985. Attachments entitled "Table I. Summary of Results Fluoride Emissions for 39B System" and "Table I. Summary of Results Potroom Group III Fluroide Emissions."

20. Dickie, R. C. in a memorandum to Robert A. McAllister, dated January 29, 1986 "Hood Inspection Summary."

APPENDIX A

DATA TABLES

Table A-1. ALUMAX ROOF MONITOR DATA.

101-G ROOF MONITOR RESULTS 1981

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
81/01/12	101-G	006	0.548	0.198	0.754	2,351	2,495	101.4
81/01/13	101-G	007	0.526	0.134	0.674	2,365	2,428	89.4
81/01/14	101-G	008	0.232	0.156	0.388	2,285	2,336	95.9
81/02/02	101-G	012	0.497	0.168	0.668	2,258	2,366	101.3
81/02/03	101-G	013	0.247	0.445	0.692	2,079	2,105	102.0
81/02/04	101-G	014	0.406	0.384	0.790	1,930	2,013	99.9
81/03/09	101-G	203	0.425	0.329	0.754	2,001	2,051	98.9
81/03/10	101-G	205	0.428	0.353	0.781	1,876	1,908	98.2
81/03/11	101-G	207	0.395	0.281	0.676	1,887	1,937	99.2
81/03/30	101-G	232	0.639	0.426	1.065	2,131	2,085	103.8
81/03/31	101-G	233	0.364	0.326	0.690	2,221	2,171	97.0
81/04/01	101-G	234	0.380	0.268	0.648	1,658	1,664	100.5
81/05/11	101-G	244	0.510	0.340	0.806	1,911	1,848	103.1
81/05/12	101-G	246	0.510	0.506	1.020	1,707	1,637	110.0
81/05/13	101-G	248	0.520	0.230	0.716	1,706	1,658	108.1
81/06/08	101-G	262	0.478	0.372	0.870	2,246	2,170	105.7
81/06/09	101-G	264	0.642	0.386	1.030	2,200	2,051	102.0
81/06/10	101-G	267	0.510	0.650	1.160	2,222	2,075	95.3
81/07/07	101-G	272	0.480	0.570	1.050	1,707	1,615	98.6
81/07/08	101-G	274	0.520	0.550	1.070	1,519	1,421	98.4
81/07/09	101-G	277	0.510	0.400	0.910	1,869	1,748	96.9
81/08/10	101-G	294	0.380	0.410	0.790	1,628	1,534	109.7
81/08/11	101-G	296	0.430	0.490	0.920	1,671	1,557	101.6
81/08/12	101-G	298	0.370	0.400	0.770	1,657	1,554	102.7
81/09/28	101-G	312	0.470	0.350	0.820	1,703	1,603	93.9
81/09/29	101-G	313	0.320	0.400	0.720	1,490	1,401	109.8
81/09/30	101-G	314	0.280	0.360	0.640	1,713	1,599	103.3
81/10/05	101-G	315	0.540	0.450	0.990	2,047	1,954	100.3
81/10/06	101-G	318	0.260	0.560	0.820	1,834	1,726	100.9
81/10/07	101-G	320	0.480	0.420	0.850	1,644	1,574	104.5
81/11/09	101-G	333	0.328	0.422	0.750	2,098	2,042	113.8
81/11/10	101-G	338	0.369	0.471	0.840	2,092	2,014	109.2
81/11/11	101-G	340	0.616	0.512	1.128	2,206	2,144	87.2
81/11/30	101-G	341	0.540	0.429	0.969	2,534	2,475	101.9
81/12/01	101-G	343	0.335	0.427	0.762	2,296	2,180	100.6
81/12/03	101-G	347	0.226	0.239	0.465	2,226	2,209	109.3

Table A-1. ALUMAX ROOF MONITOR DATA.

101-H ROOF MONITOR RESULTS 1981

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
81/01/19	101-H	016	0.374	0.214	0.588	1,454	1,472	85.9
81/01/20	101-H	017	0.404	0.350	0.760	1,839	1,850	111.3
81/02/17	101-H	019	1.087	0.569	1.656	2,078	2,081	103.9
81/02/18	101-H	020	0.654	0.450	1.063	2,198	2,206	103.8
81/02/19	101-H	021	0.369	0.760	1.136	2,242	2,187	99.7
81/03/09	101-H	204	0.416	0.342	0.764	1,354	1,379	100.0
81/03/10	101-H	206	0.464	0.371	0.835	1,455	1,462	95.9
81/03/11	101-H	208	0.609	0.359	0.968	1,464	1,463	98.8
81/04/06	101-H	235	0.772	0.406	1.180	1,577	1,551	99.0
81/04/07	101-H	236	0.459	0.419	0.878	1,361	1,371	99.4
81/04/08	101-H	237	0.538	0.326	0.864	1,789	1,786	101.8
81/05/11	101-H	245	0.600	0.500	1.090	1,791	1,708	104.2
81/05/12	101-H	247	0.240	0.210	0.450	1,753	1,694	103.3
81/05/13	101-H	249	0.480	0.230	0.710	1,733	1,676	94.8
81/06/08	101-H	263	0.730	0.410	1.140	2,249	2,140	102.7
81/06/09	101-H	265	0.410	0.560	0.970	2,106	1,931	105.0
81/06/10	101-H	266	0.640	0.650	1.290	2,179	1,995	102.0
81/07/07	101-H	273	0.660	0.490	1.150	1,748	1,656	108.9
81/07/08	101-H	275	0.420	0.340	0.760	1,822	1,727	99.8
81/07/09	101-H	276	0.335	0.420	0.770	1,563	1,462	102.7
81/08/10	101-H	295	0.340	0.410	0.750	1,311	1,260	113.7
81/08/11	101-H	297	0.350	0.390	0.740	1,289	1,216	113.7
81/08/12	101-H	299	0.250	0.310	0.560	1,385	1,285	113.6
81/08/31	101-H	301	0.550	0.340	0.890	2,172	2,042	104.0
81/09/01	101-H	303	0.400	0.280	0.680	2,040	1,944	107.2
81/09/02	101-H	304	0.630	0.410	1.040	1,776	1,697	104.3
81/10/05	101-H	316	0.400	0.430	0.830	1,514	1,450	112.5
81/10/06	101-H	317	0.340	0.530	0.870	1,425	1,343	107.8
81/10/07	101-H	319	0.460	0.580	1.040	1,626	1,545	105.6
81/11/09	101-H	334	0.352	0.579	0.931	1,599	1,505	108.9
81/11/10	101-H	336	0.279	0.374	0.653	1,548	1,508	111.9
81/11/11	101-H	339	0.305	0.513	0.818	1,608	1,493	108.6
81/11/30	101-H	342	0.352	0.323	0.675	2,260	2,253	108.0
81/12/01	101-H	344	0.564	0.356	0.920	2,269	2,202	109.0
81/12/02	101-H	346	0.394	0.432	0.826	2,160	2,092	107.1

Table A-1. ALUMAX ROOF MONITOR DATA.

103-G ROOF MONITOR RESULTS 1981

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
81/03/02	103-G	200	0.327	0.163	0.490	1,945	1,918	100.2
81/03/03	103-G	201	0.338	0.230	0.568	1,700	1,697	98.7
81/03/04	103-G	202	0.348	0.224	0.571	1,878	1,860	98.3
81/04/13	103-G	238	0.525	0.361	0.886	1,592	1,568	102.2
81/04/14	103-G	239	0.599	0.406	0.995	1,890	1,853	105.7
81/05/26	103-G	251	0.430	0.410	0.840	2,082	1,988	117.3
81/05/27	103-G	252	0.350	0.180	0.530	2,157	2,048	109.3
81/05/28	103-G	254	0.200	0.220	0.410	1,818	1,728	105.3
81/06/01	103-G	256	0.270	0.380	0.640	1,450	1,391	108.6
81/06/02	103-G	258	0.310	0.190	0.500	1,977	1,871	104.1
81/06/03	103-G	260	0.290	0.310	0.600	1,820	1,736	105.2
81/07/27	103-G	282	0.350	0.240	0.590	1,585	1,505	93.3
81/07/28	103-G	285	0.260	0.220	0.480	1,489	1,409	104.3
		287	0.350	0.310	0.670	1,454	1,382	112.7
81/08/03	103-G	288	0.630	0.340	0.970	1,640	1,583	114.6
81/08/04	103-G	290	0.280	0.380	0.660	1,692	1,606	106.3
81/08/05	103-G	292	0.350	0.140	0.400	1,553	1,458	112.3
81/09/08	103-G	306	0.406	0.390	0.796	1,560	1,465	108.1
81/09/09	103-G	308	0.458	0.545	1.004	1,470	1,380	109.5
81/09/10	103-G	310	0.341	0.445	0.786	1,460	1,392	105.6
81/10/12	103-G	321	0.276	0.343	0.620	1,787	1,718	103.4
81/10/13	103-G	323	0.405	0.573	0.978	1,758	1,705	101.1
81/10/14	103-G	325	0.299	0.380	0.679	1,765	1,715	111.0
81/11/02	103-G	327	0.332	0.541	0.872	1,912	1,855	109.5
81/11/03	103-G	329	0.294	0.535	0.829	1,919	1,845	104.6
81/11/04	103-G	331	0.257	0.428	0.685	5,250	5,035	114.4
81/12/07	103-G	348	0.248	0.212	0.460	1,745	1,736	102.3
81/12/08	103-G	350	0.225	0.299	0.524	1,779	1,717	102.1
81/12/09	103-G	352	0.305	0.305	0.609	1,744	1,740	109.1

Recorded as 0.490

0.350
0.140
0.490

Table A-1. ALUMAX ROOF MONITOR DATA.

103-H ROOF MONITOR RESULTS 1981

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
81/02/23	103-H	022	0.913	0.342	1.260	2,067	2,039	99.3
81/02/24	103-H	023	0.883	0.267	1.150	2,134	2,152	105.0
81/02/25	103-H	024	0.646	0.335	0.980	1,930	1,924	105.6
81/04/20	103-H	241	0.678	0.335	1.014	1,651	1,574	101.9
81/04/21	103-H	242	[illegible]	0.322	0.703	1,685	1,673	99.5
81/04/22	103-H	243	0.330	0.359	0.696	1,287	1,266	102.3
81/05/26	103-H	250	0.950	0.460	1.400	2,521	2,412	98.6
81/05/27	103-H	253	0.720	0.410	1.120	2,429	2,303	103.4
81/05/28	103-H	255	0.660	0.690	1.350	2,378	2,224	100.8
81/06/01	103-H	257	0.500	0.620	1.130	1,824	1,719	108.3
81/06/02	103-H	259	0.520	0.520	1.050	2,016	1,913	115.5
81/06/03	103-H	261	0.620	0.470	1.080	1,905	1,792	104.9
81/07/27	103-H	283	0.460	0.650	1.110	1,573	1,469	107.7
81/07/28	103-H	284	0.630	0.420	1.060	1,664	1,574	98.8
81/07/29	103-H	286	0.500	0.500	1.000	1,563	1,466	107.6
81/08/03	103-H	289	0.370	0.430	0.800	1,586	1,506	114.6
81/08/04	103-H	291	0.340	0.530	0.880	1,547	1,440	109.6
81/08/05	103-H	293	0.380	0.450	0.840	1,518	1,452	105.4
81/09/08	103-H	307	0.447	0.667	1.114	1,416	1,323	105.9
81/09/09	103-H	309	0.638	0.726	1.364	1,464	1,369	100.2
81/09/10	103-H	311	0.431	0.407	0.839	1,377	1,315	92.8
81/10/02	103-H	322	0.409	0.299	0.707	1,667	1,608	101.5
81/10/13	103-H	324	0.281	0.357	0.638	1,694	1,648	101.4
81/10/14	103-H	326	0.372	0.287	0.659	1,566	1,519	96.2
81/11/03	103-H	330	0.372	0.518	0.888	1,799	1,735	115.9
81/11/04	103-H	332	0.513	0.547	1.060	2,034	1,951	118.7
81/12/07	103-H	349	0.496	0.244	0.739	2,387	2,386	89.4
81/12/08	103-H	351	0.589	0.606	1.196	2,284	2,262	104.7
81/12/09	103-H	353	0.494	0.251	0.746	2,309	2,325	98.6

Table A-1. ALUMAX ROOF MONITOR DATA.

101-G ROOF MONITOR RESULTS 1982

DATE	LOC	TEST #	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
82/01/11	101-G	360	0.192	0.144	0.336	1,446	1,491	102.8
82/01/12	101-G	362	0.373	0.240	0.613	1,918	1,910	108.1
82/01/13	101-G	364	0.180	0.189	0.369	1,889	1,902	101.6
82/02/01	101-G	366	0.271	0.228	0.499	1,986	1,974	101.4
82/02/02	101-G	368	0.297	0.217	0.514	1,726	1,741	102.2
82/02/03	101-G	370	0.220	0.319	0.538	1,935	1,926	105.2
82/03/08	101-G	384	0.170	0.320	0.490	2,668	2,661	94.8
82/03/09	101-G	386	0.560	0.350	0.910	2,672	2,726	101.7
82/03/10	101-G	388	0.590	0.330	0.910	2,575	2,569	105.9
82/04/05	101-G	401	0.370	0.440	0.810	2,236	2,177	105.3
82/04/06	101-G	403	0.370	0.260	0.630	2,277	2,202	109.7
82/04/07	101-G	405	0.400	0.270	0.670	2,251	2,247	101.7
82/04/26	101-G	419	0.330	0.370	0.690	2,531	2,583	105.1
82/04/27	101-G	421	0.240	0.380	0.620	2,656	2,559	103.2
82/04/28	101-G	423	0.450	0.300	0.750	2,560	2,455	108.1
82/06/01	101-G	425	0.270	0.360	0.620	2,145	2,054	108.1
82/06/02	101-G	427	0.290	0.420	0.700	2,146	1,991	110.6
82/06/03	101-G	429	0.350	0.580	0.920	2,080	2,028	106.5
82/07/19	101-G	437	0.240	0.350	0.590	1,858	1,728	110.6
82/07/20	101-G	439	0.210	0.280	0.490	1,863	1,799	109.9
82/07/21	101-G	441	0.320	0.490	0.820	1,882	1,732	110.4
82/08/09	101-G	461	0.180	0.350	0.520	1,890	1,762	109.1
82/08/10	101-G	463	0.210	0.530	0.740	1,916	1,787	98.5
82/08/11	101-G	465	0.350	0.530	0.890	2,352	2,163	109.1
82/09/14	101-G	479	0.380	0.560	0.950	2,374	2,213	104.8
82/09/15	101-G	481	0.380	0.480	0.870	2,305	2,131	101.7
82/09/16	101-G	483	0.470	0.620	1.090	2,325	2,166	100.7
82/09/27	101-G	491	0.380	0.320	0.700	2,277	2,175	101.1
82/09/28	101-G	493	0.380	0.320	0.700	2,283	2,193	100.5
82/09/29	101-G	495	0.450	0.520	0.970	2,310	2,194	102.4
82/11/08	101-G	509	0.180	0.430	0.610	2,622	2,640	96.6
82/11/09	101-G	511	0.240	0.330	0.570	2,441	2,413	95.9
82/11/10	101-G	513	0.320	0.450	0.760	2,493	2,477	95.0
82/12/06	101-G	515	0.310	0.420	0.730	2,268	2,194	99.9
82/12/07	101-G	517	0.450	0.570	1.010	2,236	2,185	100.2
82/12/08	101-G	519	0.360	0.460	0.810	2,094	2,061	103.0

Table A-1. ALUMAX ROOF MONITOR DATA.

101-H ROOF MONITOR RESULTS 1982

DATE	LOC	TEST #	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
82/01/11	101-H	361	0.422	0.192	0.614	2,098	2,138	101.7
82/01/12	101-H	363	0.327	0.163	0.490	2,416	2,478	98.3
82/01/13	101-H	365	0.263	0.331	0.594	2,342	2,357	100.1
82/02/01	101-H	367	0.558	0.469	1.027	2,342	2,305	115.5
82/02/02	101-H	369	0.625	0.431	1.056	2,103	2,097	114.4
82/02/03	101-H	371	0.756	0.262	1.018	2,050	2,033	103.8
82/03/08	101-H	385	0.270	0.320	0.600	2,591	2,610	97.2
82/03/09	101-H	387	0.650	0.400	1.060	2,562	2,591	97.5
82/03/10	101-H	389	0.780	0.320	1.100	2,568	2,581	101.9
82/04/05	101-H	402	0.400	0.380	0.800	2,242	2,188	107.6
82/04/06	101-H	404	0.420	0.460	0.880	2,211	2,201	106.8
82/04/07	101-H	406	0.530	0.340	0.870	2,270	2,260	106.4
82/04/26	101-H	420	0.270	0.420	0.680	2,272	2,200	108.4
82/04/27	101-H	422	0.380	0.380	0.760	2,277	2,136	106.2
82/04/28	101-H	424	0.450	0.460	0.920	2,288	2,258	108.1
82/06/01	101-H	426	0.230	0.390	0.610	2,220	2,168	111.2
82/06/02	101-H	428	0.370	0.450	0.820	2,250	2,096	110.5
82/06/03	101-H	430	0.380	0.380	0.750	2,254	2,088	110.3
82/07/19	101-H	438	0.300	0.260	0.570	2,296	2,186	100.0
82/07/20	101-H	440	0.370	0.600	0.970	2,322	2,115	103.5
82/07/21	101-H	442	0.520	0.360	0.880	2,348	2,183	96.4
82/08/09	101-H	462	0.380	0.430	0.810	1,848	1,743	95.5
82/08/10	101-H	464	0.360	0.440	0.800	1,836	1,743	95.8
82/08/11	101-H	466	0.400	0.450	0.850	1,955	1,836	95.1
82/09/14	101-H	480	0.460	0.780	1.230	2,350	2,221	104.7
82/09/15	101-H	482	0.410	0.590	1.000	2,327	2,200	101.6
82/09/16	101-H	484	0.370	0.710	1.080	2,359	2,181	105.3
82/09/27	101-H	492	0.380	0.400	0.780	2,348	2,241	108.5
82/09/28	101-H	494	0.460	0.530	0.990	1,952	1,840	109.2
82/09/29	101-H	496	0.520	0.530	1.040	2,140	2,022	108.3
82/11/08	101-H	510	0.420	0.500	0.920	2,225	2,196	103.1
82/11/09	101-H	512	0.350	0.320	0.670	2,025	1,984	103.3
82/11/10	101-H	514	0.310	0.410	0.720	1,993	1,955	105.8
82/12/06	101-H	516	0.320	0.490	0.810	1,823	1,751	106.9
82/12/07	101-H	518	0.450	0.590	1.040	2,101	2,058	104.8
82/12/08	101-H	520	0.380	0.420	0.800	2,085	2,074	105.7

Table A-1. ALUMAX ROOF MONITOR DATA.

103-G ROOF MONITOR RESULTS 1982

DATE	LOC	TEST #	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
82/01/04	103-G	354	0.293	0.238	0.532	1,974	1,912.0	107.9
82/01/05	103-G	356	0.352	0.218	0.569	1,950	1,936.0	104.2
82/01/06	103-G	358	0.379	0.417	0.796	1,994	1,929.0	107.9
82/02/08	103-G	372	0.303	0.321	0.624	2,113	2,117.0	106.0
82/02/09	103-G	374	0.324	0.317	0.641	2,121	2,043.0	107.4
82/02/10	103-G	376	0.598	0.382	0.980	2,165	2,131.0	109.5
82/03/01	103-G	378	0.150	0.170	0.330	1,341	1,349.0	109.2
82/03/02	103-G	380	0.130	0.150	0.280	1,303	1,307.0	109.0
82/03/03	103-G	382	0.160	0.230	0.390	1,317	1,301.0	110.9
82/04/12	103-G	407	0.390	0.360	0.750	2,387	2,303.0	101.1
82/04/13	103-G	409	0.320	0.520	0.840	2,254	2,275.0	106.3
82/04/14	103-G	411	0.290	0.370	0.660	2,253	2,141.0	106.4
82/04/20	103-G	413	0.350	0.520	0.870	2,361	2,368.0	103.8
82/04/21	103-G	415	0.560	0.410	0.970	2,503	2,445.0	101.4
82/04/22	103-G	417	0.370	0.560	0.920	2,525	2,558.0	100.6
82/06/14	103-G	431	0.280	0.450	0.730	1,902	1,789.0	110.3
82/06/15	103-G	433	0.480	0.920	1.400	2,058	1,912.0	109.1
82/06/16	103-G	435	0.280	0.290	0.570	2,337	2,176.0	108.4
82/07/26	103-G	443	0.280	0.350	0.630	2,045	1,926.0	110.7
82/07/27	103-G	445	0.340	0.320	0.660	2,154	2,006.0	106.4
82/07/28	103-G	447	0.310	0.370	0.680	2,158	2,031.0	104.7
82/08/02	103-G	449	0.230	0.420	0.650	2,150	2,006.0	109.5
82/08/03	103-G	451	0.300	0.550	0.850	2,091	1,961.0	110.0
82/08/04	103-G	453	0.310	0.620	0.930	2,136	1,997.0	109.4
82/09/20	103-G	485	0.310	0.180	0.500	2,047	1,908.0	103.5
82/09/21	103-G	487	0.240	0.290	0.530	2,087	2,011.0	104.6
82/09/22	103-G	489	0.220	0.260	0.480	2,112	2,035.0	98.6
82/10/04	103-G	497	0.350	0.420	0.770	2,004	1,894.0	103.9
82/10/05	103-G	499	0.430	0.250	0.680	2,005	1,893.0	100.1
82/10/06	103-G	501	0.560	0.700	1.270	1,953	1,832.0	106.6
82/11/01	103-G	503	0.380	0.380	0.760	1,916	1,827.0	106.4
82/11/02	103-G	505	0.380	0.320	0.690	1,896	1,802.0	104.6
82/11/03	103-G	507	0.340	0.400	0.740	1,924	1,827.0	103.1
82/12/20	103-G	521	0.270	0.290	0.570	1,858	1,889.0	106.9
82/12/21	103-G	523	0.160	0.160	0.320	1,900	1,869.0	104.7
82/12/22	103-G	525	0.260	0.340	0.600	1,833	1,827.0	102.8

Table A-1. ALUMAX ROOF MONITOR DATA.

103-H ROOF MONITOR RESULTS 1982

DATE	LOC	TEST #	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
82/01/04	103-H	355	0.496	0.551	1.047	2,139	2,050	116.6
82/01/05	103-H	357	0.324	0.316	0.640	2,140	2,137	107.4
82/01/06	103-H	359	0.360	0.422	0.782	2,095	2,069	109.5
82/02/08	103-H	373	0.344	0.291	0.635	2,163	2,171	105.1
82/02/09	103-H	375	0.527	0.542	1.069	2,069	2,075	106.0
82/02/10	103-H	377	0.558	0.352	0.909	2,152	2,137	102.2
82/03/01	103-H	379	0.240	0.240	0.480	1,546	1,552	97.7
82/03/02	103-H	381	0.300	0.300	0.600	1,538	1,527	97.9
82/03/03	103-H	383	0.260	0.470	0.730	1,467	1,458	106.1
82/04/12	103-H	408	0.510	0.340	0.850	2,147	2,097	105.7
82/04/13	103-H	410	0.430	0.540	0.970	2,060	2,001	114.8
82/04/14	103-H	412	0.290	0.390	0.680	2,137	2,027	105.9
82/04/20	103-H	414	0.430	0.360	0.790	2,031	1,946	105.2
82/04/21	103-H	416	0.560	0.560	1.120	2,373	2,282	102.3
82/04/22	103-H	418	0.280	0.500	0.780	2,169	2,118	105.7
82/06/14	103-H	432	0.520	0.420	0.940	2,202	2,063	108.6
82/06/15	103-H	434	0.350	0.320	0.670	2,326	2,191	110.7
82/06/16	103-H	436	0.470	0.520	1.000	2,324	2,148	109.7
82/07/26	103-H	444	[illegible]	0.820	1.420	2,342	2,145	107.6
82/07/27	103-H	446	0.400	0.590	0.990	2,121	1,964	104.3
82/07/28	103-H	448	0.690	0.450	1.140	2,966	2,722	109.7
82/08/02	103-H	450	0.510	0.820	1.330	2,669	2,504	107.7
82/08/03	103-H	452	0.470	0.650	1.120	2,435	2,258	108.7
82/08/04	103-H	454	0.430	0.470	0.900	2,426	2,260	108.6
82/09/20	103-H	486	0.440	0.500	0.940	2,413	2,315	104.5
82/09/21	103-H	488	0.340	0.580	0.920	2,486	2,306	102.0
82/09/22	103-H	490	0.330	0.860	1.200	2,422	2,270	105.5
82/10/04	103-H	498	0.310	0.440	0.750	2,033	1,920	101.8
82/10/05	103-H	500	0.270	0.550	0.820	2,049	1,917	108.0
82/10/06	103-H	502	0.260	0.300	0.560	2,043	1,942	105.9
82/11/01	103-H	504	0.340	0.670	1.020	2,052	1,956	108.1
82/11/02	103-H	506	0.340	0.670	1.020	2,052	1,956	108.1
82/11/03	103-H	508	0.340	0.330	0.670	2,019	1,895	106.4
82/12/20	103-H	522	0.220	0.220	0.440	1,830	1,864	119.1
82/12/21	103-H	524	0.300	0.280	0.580	1,912	1,888	107.3
82/12/22	103-H	526	0.120	0.120	0.240	1,930	1,921	115.2

Table A-1. ALUMAX ROOF MONITOR DATA.

101-G ROOF MONITOR RESULTS 1983

DATE	LOC	TEST #	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
83/01/10	101-G	001	0.23	0.31	0.55	1,792	1,749	101.5
83/01/11	101-G	003	0.43	0.34	0.78	2,456	2,403	98.9
83/01/12	101-G	005	0.44	0.29	0.72	2,454	2,428	98.1
83/02/07	101-G	025	0.38	0.21	0.59	1,515	1,526	102.0
83/02/08	101-G	027	0.28	0.16	0.44	1,604	1,628	103.5
83/02/09	101-G	029	0.19	0.23	0.42	1,599	1,622	102.6
83/02/28	101-G	035	0.40	0.41	0.81	1,758	1,745	107.7
83/03/01	101-G	037	0.32	0.37	0.69	1,777	1,733	106.0
83/03/02	101-G	039	0.26	0.34	0.60	2,069	2,030	101.8
83/03/28	101-G	051	0.19	0.32	0.51	2,134	2,080	90.6
83/03/29	101-G	053	0.16	0.29	0.44	1,671	1,653	99.3
83/03/30	101-G	056	0.29	0.41	0.70	1,921	1,905	105.3
83/05/02	101-G	073	0.32	0.58	0.90	2,057	1,943	105.7
83/05/03	101-G	075	0.35	0.44	0.79	2,090	1,964	103.4
83/05/04	101-G	077	0.38	0.39	0.77	2,457	2,376	95.3
83/06/06	101-G	085	0.31	0.69	1.01	1,978	1,848	99.4
83/06/07	101-G	087	0.43	0.34	0.77	1,993	1,861	101.2
83/06/08	101-G	089	0.51	0.80	1.31	1,972	1,857	102.7
83/07/11	101-G	107	0.34	0.46	0.80	1,951	1,815	97.9
83/07/12	101-G	109	0.30	0.55	0.85	1,805	1,674	100.1
83/07/13	101-G	111	0.43	0.45	0.89	1,742	1,607	107.2
83/08/08	101-G	117	.44	0.68	1.12	2,122	1,992	110.0
83/08/09	101-G	119	0.42	0.63	1.05	2,284	2,085	99.5
83/08/10	101-G	121	0.60	0.70	1.29	2,031	1,851	123.8
83/09/12	101-G	144	0.23	0.39	0.62	1,921	1,774	96.4
83/09/13	101-G	146	0.31	0.51	0.82	1,948	1,803	105.1
83/09/14	101-G	148	0.42	0.53	0.95	1,985	1,867	98.1
83/10/10	101-G	167	0.37	0.63	0.63	1,939	1,841	109.9
83/10/11	101-G	169	0.35	0.87	1.23	1,828	1,708	117.0
83/10/12	101-G	171	0.33	0.66	1.00	2,290	2,120	102.7
83/11/07	101-G	193	0.31	0.43	0.74	2,348	2,314	93.0
83/11/08	101-G	195	0.33	0.66	0.98	1,671	1,605	110.4
83/11/09	101-G	197	0.27	0.54	0.81	1,704	1,653	111.2
83/11/28	101-G	205	0.43	0.59	1.02	1,937	1,850	109.0
83/11/29	101-G	207	0.23	0.26	0.49	1,956	1,935	100.5
83/11/30	101-G	209	0.09	0.38	0.47	1,643	1,652	109.9

Table A-1. ALUMAX ROOF MONITOR DATA.

101-H ROOF MONITOR RESULTS 1983

DATE	LOC	TEST #	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
83/01/10	101-H	002	0.30	0.35	0.65	1,874	1,848	104.6
83/01/11	101-H	004	0.34	0.58	0.92	1,915	1,881	103.2
83/01/12	101-H	006	0.41	0.37	0.78	1,930	1,921	104.9
83/02/07	101-H	026	0.25	0.56	0.81	1,781	1,736	108.2
83/02/08	101-H	028	0.37	0.37	0.74	2,213	2,207	97.8
83/02/09	101-H	030	0.38	0.63	1.01	2,151	2,125	105.1
83/02/28	101-H	036	0.21	0.28	0.49	1,978	1,971	103.1
83/03/01	101-H	038	0.35	0.70	1.05	1,977	1,924	107.0
83/03/02	101-H	040	0.30	0.32	0.62	1,996	1,920	99.4
83/03/28	101-H	052	0.31	0.46	0.78	1,892	1,824	98.8
83/03/29	101-H	054	0.32	0.36	0.69	1,900	1,898	97.2
83/03/30	101-H	055	0.25	0.34	0.59	1,814	1,794	100.1
83/05/02	101-H	074	0.34	0.71	1.05	1,990	1,894	108.3
83/05/03	101-H	076	0.33	0.40	0.73	2,146	2,017	107.8
83/05/04	101-H	078	0.46	0.61	1.07	2,426	2,320	100.3
83/06/06	101-H	086	0.26	0.69	0.95	1,664	1,531	107.2
83/06/07	101-H	088	0.32	0.66	0.99	1,915	1,787	103.0
83/06/08	101-H	090	0.27	0.51	0.78	1,922	1,798	100.3
83/07/11	101-H	108	0.34	0.70	1.04	2,007	1,851	110.3
83/07/12	101-H	110	0.25	0.69	0.95	1,732	1,588	112.9
83/07/13	101-H	112	0.25	0.69	0.95	1,732	1,588	112.9
83/08/08	101-H	118	0.31	0.51	0.83	2,048	1,874	107.4
83/08/09	101-H	120	0.35	0.81	1.16	2,176	2,011	100.7
83/08/10	101-H	122	0.40	0.75	1.14	2,056	1,931	103.3
83/09/12	101-H	145	0.24	0.53	0.77	1,846	1,681	107.0
83/09/13	101-H	147	0.25	0.50	0.75	1,974	1,834	103.4
83/09/14	101-H	149	0.33	0.62	0.95	1,934	1,804	99.4
83/10/10	101-H	168	0.22	0.42	0.64	1,812	1,729	101.1
83/10/11	101-H	170	0.29	0.60	0.89	1,357	1,282	118.5
83/10/12	101-H	172	0.36	0.56	0.92	2,055	1,902	102.5
83/11/07	101-H	194	0.32	0.50	0.82	1,744	1,717	104.8
83/11/08	101-H	196	0.24	0.67	0.91	1,782	1,674	102.1
83/11/09	101-H	198	0.18	0.76	0.94	1,803	1,724	95.9
83/11/28	101-H	206	0.28	0.43	0.72	1,652	1,544	98.9
83/11/29	101-H	208	0.45	0.41	0.87	1,782	1,724	105.0
83/11/30	101-H	210	0.39	0.53	0.92	1,859	1,818	101.5

Table A-1. ALUMAX ROOF MONITOR DATA.

103-G ROOF MONITOR RESULTS 1983

DATE	LOC	TEST #	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
83/01/17	103-G	007	0.16	0.16	0.32	1,147	1,144	103.3
83/01/18	103-G	009	0.29	0.21	0.49	1,834	1,854	100.6
83/01/19	103-G	011	0.42	0.37	0.80	1,754	1,789	95.0
83/01/31	103-G	019	0.50	0.47	0.97	1,968	1,926	104.6
83/02/01	103-G	021	0.59	0.66	1.25	2,073	2,016	104.2
83/02/02	103-G	023	0.41	0.38	0.79	2,074	1,957	102.4
83/03/08	103-G	041	0.28	0.32	0.60	1,841	1,763	108.1
83/03/09	103-G	043	0.27	0.32	0.59	2,032	1,934	98.6
83/03/10	103-G	045	0.33	0.17	0.50	2,048	2,047	100.7
83/04/04	103-G	057	0.35	0.36	0.71	2,080	2,024	101.5
83/04/05	103-G	059	0.33	0.47	0.80	2,398	2,355	107.1
83/04/06	103-G	061	0.24	0.37	0.61	2,542	2,484	104.7
83/04/25	103-G	067	0.20	0.23	0.43	1,557	1,508	102.8
83/04/26	103-G	069	0.21	0.2.	0.42	1,656	1,612	101.4
83/04/27	103-G	071	0.23	0.21	0.45	1,597	1,543	104.7
83/06/13	103-G	091	0.49	0.65	1.14	1,868	1,769	108.3
83/06/14	103-G	093	0.57	0.62	1.19	1,946	1,861	96.4
83/06/15	103-G	095	0.58	0.45	1.03	1,991	1,879	103.2
83/07/05	103-G	103	0.48	0.37	0.85	1,823	1,686	106.5
83/07/06	103-G	105	0.33	0.34	0.67	1,795	1,687	104.2
83/07/07	103-G	101	0.58	0.43	1.01	1,833	1,694	103.2
83/08/15	103-G	123	0.30	0.49	0.79	1,823	1,725	95.0
83/08/16	103-G	125	0.56	0.65	1.21	1,820	1,758	90.6
83/08/17	103-G	127	0.88	0.47	1.35	1,786	1,647	107.7
83/09/06	103-G	138	0.23	0.33	0.55	1,796	1,667	102.5
83/09/07	103-G	140	0.21	0.30	0.51	1,817	1,679	102.2
83/09/08	103-G	142	0.30	0.44	0.74	1,783	1,658	96.6
83/10/17	103-G	173	0.37	0.50	0.87	1,985	1,916	104.5
83/10/18	103-G	175	0.28	0.45	0.3[illegible] 0.73	1,989	1,897	94.3
83/10/19	103-G	177	0.31	0.49	0.80	1,991	1,895	103.8
83/10/31	103-G	187	0.40	0.51	0.92	2,008	1,990	102.1
83/11/01	103-G	189	0.39	0.57	0.95	2,209	2,148	98.0
83/11/02	103-G	191	0.36	0.56	0.92	2,133	2,074	100.3
83/12/05	103-G	211	0.41	0.55	0.96	2,207	2,129	101.9
83/12/06	103-G	213	0.49	0.53	1.02	2,243	2,123	105.5
83/12/07	103-G	215	0.35	0.33	0.68	2,014	2,003	96.4

[illegible] 0.73 = 0.28+0.45

Table A-1. ALUMAX ROOF MONITOR DATA.

103-H ROOF MONITOR RESULTS 1983

DATE	LOC	TEST #	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
83/01/17	103-H	008	0.15	0.18	0.33	1,152	1,148	135.6
83/01/18	103-H	010	0.34	0.17	0.51	1,834	1,864	94.0
83/01/19	103-H	012	0.17	0.10	0.27	1,617	1,676	92.3
83/01/31	103-H	020	0.27	0.56	0.83	1,890	1,832	103.9
83/02/01	103-H	022	0.47	0.60	1.08	2,043	1,954	104.4
83/02/02	103-H	024	0.36	0.34	0.70	2,084	1,971	100.2
83/03/08	103-H	042	1.13	0.54	1.67	2,424	2,312	108.8
83/03/09	103-H	044	0.56	0.47	1.03	2,406	2,256	99.9
83/03/10	103-H	046	0.31	0.32	0.62	2,421	2,361	98.6
83/04/04	103-H	058	0.31	0.32	0.62	2,421	2,361	98.6
83/04/05	103-H	060	0.28	0.49	0.77	2,710	2,610	100.3
83/04/06	103-H	062	0.32	0.45	0.77	2,679	2,527	97.2
83/04/25	103-H	068	0.33	0.40	0.73	2,434	2,342	104.1
83/04/26	103-H	070	0.41	0.53	0.94	2,191	2,085	108.8
83/04/27	103-H	072	0.46	0.55	1.01	2,061	1,970	108.4
83/06/13	103-H	092	0.30	0.48	0.78	2,261	2,149	99.5
83/06/14	103-H	094	0.47	0.47	0.94	2,211	2,068	105.7
83/06/15	103-H	096	0.35	0.51	0.86	2,115	1,967	110.0
83/07/05	103-H	104	0.51	0.57	1.08	2,046	1,891	105.3
83/07/06	103-H	106	0.46	0.59	1.05	2,090	1,922	109.3
83/07/07	103-H	102	0.40	0.40	0.79	1,937	1,816	120.0
83/08/15	103-H	124	0.26	0.42	0.68	2,032	1,912	109.9
83/08/16	103-H	126	0.31	0.55	0.86	2,215	2,077	91.7
83/08/17	103-H	128	0.25	0.46	0.71	2,265	2,111	98.2
83/09/06	103-H	139	0.30	0.59	0.89	2,010	1,839	106.8
83/09/07	103-H	141	0.30	0.57	0.87	2,074	1,885	100.6
83/09/08	103-H	143	0.35	0.61	0.96	2,086	1,930	102.6
83/10/17	103-H	174	0.17	0.38	0.55	1,915	1,838	107.5
83/10/18	103-H	176	0.35	0.46	0.80	2,161	2,063	95.9
83/10/19	103-H	178	0.33	0.38	0.71	1,880	1,795	106.2
83/10/31	103-H	188	0.31	0.40	0.71	2,048	1,994	101.8
83/11/01	103-H	190	0.33	0.35	0.68	1,919	1,866	108.5
83/11/02	103-H	192	0.24	0.37	0.61	1,936	1,886	107.7
83/12/05	103-H	212	0.27	0.48	0.76	1,686	1,607	104.4
83/12/06	103-H	214	0.33	0.64	0.97	1,580	1,530	107.3
83/12/07	103-H	216	0.30	0.29	0.58	1,736	1,719	94.0

Table A-1. ALUMAX ROOF MONITOR DATA.

101-G ROOF MONITOR RESULTS 1984

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
84/01/09	101-G	218	0.28	0.59	0.87	2,000	1,955	97.5
84/01/10	101-G	220	0.21	0.48	0.69	1,938	1,894	109.0
84/01/11	101-G	222	0.39	0.45	0.84	2,290	2,267	86.2
84/02/06	101-G	245	0.46	0.41	0.86	2,137	2,130	98.2
84/02/07	101-G	247	0.36	0.29	0.65	1,945	1,966	98.2
84/02/08	101-G	249	0.43	0.37	0.80	1,777	1,790	101.8
84/02/27	101-G	251	0.50	0.43	0.92	1,997	1,930	109.1
84/02/28	101-G	253	0.45	0.41	0.85	2,136	2,111	101.2
84/02/29	101-G	255	0.35	0.36	0.71	1,616	1,622	103.5
84/04/09	101-G	269	0.55	0.43	0.98	1,786	1,728	106.8
84/04/10	101-G	271	0.39	0.36	0.76	2,244	2,210	97.3
84/04/11	101-G	273	0.46	0.38	0.84	1,689	1,644	104.5
84/04/30	101-G	275	0.25	0.39	0.64	1,896	1,787	108.1
84/05/01	101-G	277	0.30	0.33	0.63	2,009	1,926	100.0
84/05/02	101-G	279	0.40	0.43	0.83	1,741	1,645	105.3
84/06/11	101-G	287	0.40	0.34	0.74	1,980	1,852	101.9
84/06/12	101-G	289	0.43	0.31	0.74	1,953	1,812	102.7
84/06/13	101-G	291	0.24	0.37	0.61	1,859	1,723	112.5
84/07/02	101-G	306	0.22	0.62	0.84	2,077	1,940	108.7
84/07/03	101-G	308	0.23	0.34	0.57	2,092	2,004	109.5
84/07/04	101-G	310	0.20	0.40	0.60	2,130	1,972	103.8
84/08/13	101-G	324	0.62	0.62	1.23	2,037	1,876	107.3
84/08/14	101-G	326	0.33	0.29	0.62	2,073	1,898	107.1
84/08/15	101-G	328	0.39	0.47	0.86	2,004	1,845	107.6
84/09/04	101-G	330	0.35	0.27	0.62	2,047	1,911	114.9
84/09/05	101-G	332	0.37	0.49	0.87	2,158	2,038	99.8
84/09/06	101-G	334	0.39	0.32	0.71	2,177	2,069	100.7
84/10/15	101-G	353	0.53	0.50	1.04	2,278	2,157	102.4
84/10/17	101-G	355	0.45	0.56	1.01	2,040	1,924	110.4
		357	0.40	0.53	0.92	2,136	2,004	106.9
84/10/29	101-G	371	0.39	0.41	0.81	2,230	2,077	107.4
84/10/30	101-G	373	0.36	0.42	0.78	2,075	1,974	105.3
84/10/31	101-G	375	0.33	0.42	0.74	2,078	1,968	108.2
84/12/10	101-G	399	0.18	0.30	0.48	1,415	1,386	104.7
84/12/11	101-G	401	0.33	0.26	0.59	1,461	1,429	105.3
84/12/12	101-G	403	0.27	0.28	0.54	1,889	1,861	99.1

Table A-1. ALUMAX ROOF MONITOR DATA.

101-H ROOF MONITOR RESULTS 1984

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
84/01/09	101-H	219	0.29	0.46	0.74	1,647	1,616	84.1
84/01/10	101-H	221	0.25	0.57	0.82	1,421	1,371	113.5
84/01/11	101-H	223	0.47	0.65	1.12	1,730	1,672	93.5
84/02/06	101-H	246	0.73	0.43	1.16	1,847	1,819	117.4
84/02/07	101-H	248	0.38	0.40	0.79	1,745	1,768	104.5
84/02/08	101-H	250	0.25	0.26	0.51	1,629	1,650	95.8
84/02/27	101-H	252	0.22	0.47	0.68	1,628	1,571	103.4
84/02/28	101-H	254	0.43	0.53	0.96	1,574	1,554	105.7
84/02/29	101-H	256	0.43	0.34	0.77	2,030	2,027	95.2
84/04/09	101-H	270	0.34	0.44	0.78	1,808	1,746	113.3
84/04/10	101-H	272	0.40	0.81	1.21	2,063	2,017	100.4
84/04/11	101-H	274	0.26	0.38	0.64	1,752	1,725	108.0
84/04/30	101-H	276	0.28	0.48	0.77	1,797	1,732	109.3
84/05/01	101-H	278	0.34	0.59	0.93	1,861	1,749	98.1
84/05/02	101-H	280	0.22	0.37	0.59	1,819	1,764	108.4
84/06/11	101-H	288	0.27	0.42	0.70	1,734	1,642	102.3
84/06/12	101-H	290	0.66	0.45	1.11	1,949	1,877	106.4
84/06/13	101-H	292	0.29	0.42	0.71	2,025	1,908	99.0
84/07/02	101-H	307	0.30	0.39	0.70	1,789	1,656	102.6
84/07/03	101-H	309	0.21	0.53	0.73	1,769	1,637	102.9
84/07/04	101-H	311	0.28	0.53	0.81	1,757	1,632	107.1
84/08/13	101-H	325	0.42	0.49	0.91	2,133	1,947	99.9
84/08/14	101-H	327	0.41	0.58	0.99	1,931	1,794	106.3
84/08/15	101-H	329	0.50	0.62	1.12	2,234	2,034	101.6
84/09/04	101-H	331	0.37	0.48	0.85	2,077	1,917	102.6
84/09/05	101-H	333	0.46	0.56	1.02	2,147	2,103	111.4
84/09/06	101-H	335	0.25	0.24	0.49	2,195	2,086	105.7
84/10/15	101-H	354	0.37	0.74	1.11	1,998	1,897	109.1
84/10/17	101-H	356	0.48	0.65	1.13	1,781	1,668	110.2
		358	0.32	0.34	0.67	1,891	1,776	109.4
84/10/29	101-H	372	0.30	0.73	1.03	1,995	1,852	105.3
84/10/30	101-H	374	0.39	0.45	0.84	2,023	1,891	99.9
84/10/31	101-H	376	0.42	0.72	1.14	2,349	2,210	100.3
84/12/10	101-H	400	0.30	0.42	0.72	1,477	1,425	102.8
84/12/11	101-H	402	0.41	0.52	0.93	1,688	1,635	112.8
84/12/12	101-H	404	0.60	0.67	1.27	1,948	1,901	104.3

Table A-1. ALUMAX ROOF MONITOR DATA.

103-G ROOF MONITOR RESULTS 1984

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
84/01/16	103-G	224	0.25	0.38	0.63	1,603	1,581	105.1
84/01/17	103-G	226	0.34	0.52	0.86	1,456	1,445	102.8
84/01/18	103-G	228	0.24	0.46	0.70	2,024	1,977	108.0
84/01/30	103-G	233	0.28	0.29	0.57	1,683	1,666	104.2
84/01/31	103-G	235	0.25	0.28	0.53	1,733	1,757	98.9
84/02/01	103-G	237	0.25	0.30	0.55	1,573	1,598	95.5
84/03/05	103-G	257	0.37	0.39	0.75	1,460	1,383	107.8
84/03/06	103-G	259	0.34	0.28	0.62	1,504	1,414	113.9
84/03/07	103-G	261	0.33	0.43	0.74	1,574	1,539	101.1
84/04/02	103-G	263	0.50	0.44	0.94	2,195	2,162	95.5
84/04/03	103-G	265	0.47	0.63	1.10	2,026	1,956	105.2
84/04/04	103-G	267	0.34	0.40	0.74	1,711	1,620	108.4
84/05/14	103-G	281	0.23	0.37	0.61	1,723	1,607	105.4
84/05/15	103-G	283	0.43	0.46	0.88	2,039	1,911	96.7
84/05/16	103-G	285	0.45	0.51	0.96	1,684	1,634	103.7
84/06/05	103-G	293	0.42	0.51	0.94	1,915	1,762	108.1
84/06/06	103-G	295	0.42	0.52	0.94	2,029	1,873	91.5
84/06/07	103-G	297	0.50	0.48	0.98	1,974	1,861	100.8
84/07/16	103-G	312	0.41	0.39	0.80	2,189	2,025	99.9
84/07/17	103-G	314	0.52	0.46	0.98	2,082	1,966	101.9
84/07/18	103-G	316	0.40	0.68	1.08	2,073	1,928	101.0
84/08/07	103-G	318	0.37	0.34	0.71	1,942	1,792	99.1
84/08/08	103-G	320	0.34	0.40	0.74	1,696	1,571	107.5
84/08/09	103-G	322	0.29	0.45	0.74	1,776	1,622	102.1
84/09/10	103-G	336	0.24	0.47	0.71	2,175	2,028	103.3
84/09/11	103-G	338	0.33	0.37	0.70	2,402	2,234	107.9
84/09/12	103-G	340	0.29	0.30	0.59	2,344	2,170	102.3
84/10/01	103-G	347	0.45	0.31	0.76	2,727	2,624	105.2
84/10/02	103-G	349	0.33	0.23	0.56	2,228	2,171	108.6
84/10/03	103-G	351	0.26	0.23	0.49	2,344	2,281	102.8
84/11/05	103-G	377	0.15	0.34	0.49	2,292	2,209	98.1
84/11/06	103-G	379	0.32	0.43	0.78	2,[illegible]6	2,029	109.1
84/11/07	103-G	381	0.47	0.26	0.72	2,240	2,228	103.7
84/12/03	103-G	393	0.50	0.52	1.01	2,308	2,241	105.8
84/12/04	103-G	395	0.44	.	0.93	2,367	2,339	102.1
84/12/05	103-G	397	0.41	0.59	1.00	1,997	1,963	106.1

Table A-1. ALUMAX ROOF MONITOR DATA.

103-H ROOF MONITOR RESULTS 1984

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
84/01/16	103-H	225	0.33	0.30	0.64	1,491	1,478	99.8
84/01/17	103-H	227	0.27	0.34	0.61	1,543	1,513	110.0
84/01/18	103-H	229	0.43	0.39	0.82	1,465	1,424	105.8
84/01/30	103-H	234	0.31	0.46	0.77	1,502	1,459	106.1
84/01/31	103-H	236	0.24	0.30	0.54	1,470	1,453	113.1
84/02/01	103-H	238	0.21	0.27	0.48	1,231	1,242	112.1
84/03/05	103-H	258	0.26	0.37	0.63	1,964	1,882	100.6
84/03/06	103-H	260	0.33	0.51	0.84	1,918	1,813	95.9
84/03/07	103-H	262	0.50	0.62	1.12	1,888	1,873	105.5
84/04/02	103-H	264	0.31	0.40	0.71	1,893	1,855	98.0
84/04/03	103-H	266	0.28	0.55	0.83	1,787	1,749	102.6
84/04/04	103-H	268	0.54	0.82	1.37	1,856	1,749	100.0
84/05/14	103-H	282	0.52	0.58	1.10	2,046	1,930	102.3
84/05/15	103-H	284	0.47	0.39	0.86	1,896	1,751	93.0
84/05/16	103-H	286	0.39	0.39	0.79	1,788	1,761	103.8
84/06/05	103-H	294	0.37	0.53	0.91	2,006	1,898	107
84/06/06	103-H	296	0.38	0.50	0.88	2,161	1,996	92.2
84/06/07	103-H	298	0.21	0.46	0.68	1,684	1,564	109.6
84/07/16	103-H	313	0.36	0.50	0.86	1,975	1,826	113.1
84/07/17	103-H	315	0.36	0.60	0.96	2,111	1,919	111.6
84/07/18	103-H	317	0.38	0.46	0.84	1,872	1,729	111.9
84/08/07	103-H	319	0.49	0.96	1.45	2,160	1,972	98.9
84/08/08	103-H	321	0.38	0.94	1.32	1,858	1,682	101.1
84/08/09	103-H	323	0.41	0.76	1.17	1,893	1,708	95.3
84/09/10	103-H	337	0.30	0.37	0.67	2,238	2,085	110.0
84/09/11	103-H	339	0.43	0.59	1.02	2,349	2,205	113.0
84/09/12	103-H	341	0.35	0.57	0.92	2,253	2,051	105.6
84/10/01	103-H	348	0.46	0.52	0.98	2,415	2,301	107.7
84/10/02	103-H	350	0.28	0.38	0.67	2,322	2,250	111.6
84/10/03	103-H	352	0.27	0.32	0.59	2,307	2,214	105.5
84/11/05	103-H	378	0.49	0.53	1.02	2,031	1,923	100.3
84/11/06	103-H	380	0.41	0.28	0.69	2,128	2,068	103.2
84/11/07	103-H	382	0.42	0.34	0.76	2,243	2,231	99.0
84/12/03	103-H	394	0.23	0.57	0.80	2,374	2,305	104.8
84/12/04	103-H	396	0.37	0.38	0.75	2,480	2,454	107.9
84/12/05	103-H	398	0.37	0.20	0.57	1,633	1,582	106.9

Table A-1. ALUMAX ROOF MONITOR DATA.

101-G ROOF MONITOR RESULTS 1985

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
85/01/07	101-G	405	0.420	0.2500	0.670	1,567.0	1,545.0	108.4
85/01/08	101-G	407	0.450	0.2000	0.650	1,543.0	1,525.0	106.0
85/01/09	101-G	409	0.250	0.2200	0.470	1,548.0	1,536.0	107.0
85/02/11	101-G	426	0.370	0.6700	1.040	1,820.0	1,763.0	106.6
85/02/12	101-G	428	0.410	0.4300	0.830	1,474.0	1,450.0	112.7
85/02/13	101-G	430	0.140	0.3100	0.450	1,440.0	1,420.0	105.9
85/03/04	101-G	435	0.208	0.3580	0.566	2,251.0	2,165.0	104.2
85/03/05	101-G	437	0.209	0.3720	0.580	1,556.0	1,485.0	112.7
85/03/06	101-G	439	0.378	0.3000	0.679	1,607.8	1,581.7	109.0

101-H ROOF MONITOR RESULTS 1985

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
85/01/07	101-H	406	0.370	0.400	0.770	1,484.0	1,436.0	100.2
85/01/08	101-H	408	0.540	0.460	0.990	1,857.0	1,811.0	104.8
85/01/09	101-H	410	0.700	0.710	1.410	1,817.0	1,788.0	94.8
85/02/11	101-H	427	0.370	0.360	0.730	976.0	955.0	102.4
85/02/12	101-H	429	0.160	0.800	0.960	1,564.0	1,529.0	106.8
85/02/13	101-H	431	0.090	0.330	0.420	1,387.0	1,363.0	105.5
85/03/04	101-H	436	0.582	0.510	1.093	1,655.0	1,603.0	109.2
85/03/05	101-H	438	0.308	0.612	0.920	1,511.6	1,438.2	108.2
85/03/06	101-H	440	0.377	0.193	0.570	1,946.1	1,921.5	107.6

Table A-1. ALUMAX ROOF MONITOR DATA.

103-G ROOF MONITOR RESULTS 1985

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
85/01/14	103-G	411	0.16	0.14	0.30	1,630	1,602	103.2
85/01/15	103-G	413	0.17	0.18	0.35	1,582	1,563	108.1
85/01/16	103-G	415	0.27	0.32	0.58	1,361	1,354	107.5
85/02/04	103-G	420	0.41	0.42	0.82	2,304	2,277	102.3
85/02/05	103-G	422	0.20	0.41	0.61	2,049	2,030	103.6
85/02/06	103-G	424	0.23	0.49	0.72	2,077	1,983	108.8

103-H ROOF MONITOR RESULTS 1985

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
85/01/14	103-H	412	0.25	0.19	0.45	1,079	1,065	103.4
85/01/15	103-H	414	0.23	0.26	0.48	1,265	1,254	106.3
85/01/16	103-H	416	0.15	0.18	0.33	1,202	1,209	94.0
85/02/04	103-H	421	0.41	0.33	0.73	2,430	2,451	100.1
85/02/05	103-H	423	0.26	0.37	0.63	1,526	1,531	112.8
85/02/06	103-H	425	0.22	0.33	0.55	1,468	1,435	103.4

Table A-1. ALUMAX ROOF MONITOR DATA.

101-G ROOF MONITOR RESULTS 1985

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
85/01/07	101-G	405	0.420	0.250	0.670	1,567	1,545	108.4
85/01/08	101-G	407	0.450	0.200	0.650	1,543	1,525	106.0
85/01/09	101-G	409	0.250	0.220	0.470	1,548	1,536	107.0
85/02/11	101-G	426	0.370	0.670	1.040	1,820	1,763	106.6
85/02/12	101-G	428	0.410	0.430	0.830	1,474	1,450	112.7
85/02/13	101-G	430	0.140	0.310	0.450	1,440	1,420	105.9
85/03/04	101-G	435	0.210	0.360	0.570	2,251	2,165	104.2
85/03/05	101-G	437	0.210	0.370	0.580	1,556	1,485	112.7
85/03/06	101-G	439	0.380	0.300	0.680	1,607	1,581	109.0
85/04/16	101-G	455	0.270	0.210	0.480	1,537	1,472	104.7
85/04/17	101-G	457	0.290	0.390	0.680	1,644	1,572	101.2
85/04/18	101-G	459	0.240	0.390	0.630	1,404	1,354	103.1
85/05/06	101-G	461	0.320	0.380	0.700	1,754	1,680	103.2
85/05/07	101-G	463	0.430	0.390	0.820	2,088	1,972	101.7
85/05/08	101-G	465	0.190	0.200	0.390	1,902	1,809	106.2
85/06/10	101-G	485	0.200	0.410	0.610	1,735	1,591	115.4
85/06/11	101-G	487	0.540	0.360	0.900	1,515	1,405	111.6
85/06/12	101-G	489	0.300	0.340	0.640	1,543	1,438	105.8
85/07/08	101-G	497	0.284	0.419	0.703	1,629	1,513	107.0
85/07/09	101-G	499	0.311	0.321	0.632	1,420	1,307	99.1
85/07/10	101-G	501	0.343	0.316	0.660	1,521	1,383	102.8
85/08/12	101-G	515	0.636	0.314	0.950	1,795	1,666	96.9
85/08/13	101-G	517	0.385	0.459	0.843	2,283	2,138	96.6
85/08/14	101-G	519	0.426	0.542	0.968	2,231	2,093	96.0

Table A-1. ALUMAX ROOF MONITOR DATA.

101-H ROOF MONITOR RESULTS 1985

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
85/01/07	101-H	406	0.370	0.400	0.770	1,484	1,436	100.2
85/01/08	101-H	408	0.540	0.460	0.990	1,857	1,811	104.8
85/01/09	101-H	410	0.700	0.710	1.410	1,817	1,788	94.8
85/02/11	101-H	427	0.370	0.360	0.730	976	955	102.4
85/02/12	101-H	429	0.160	0.800	0.960	1,564	1,529	106.8
85/02/13	101-H	431	0.090	0.330	0.420	1,387	1,363	105.5
85/03/04	101-H	436	0.580	0.510	1.090	1,655	1,603	109.2
85/03/05	101-H	438	0.310	0.610	0.920	1,511	1,438	108.2
85/03/06	101-H	440	0.380	0.190	0.570	1,946	1,921	107.6
85/04/16	101-H	456	0.400	0.450	0.840	1,664	1,572	111.2
85/04/17	101-H	458	0.260	0.430	0.680	1,488	1,419	111.0
85/04/18	101-H	460	0.240	0.340	0.580	1,628	1,573	115.1
85/05/06	101-H	462	0.340	0.530	0.870	1,695	1,604	110.8
85/05/07	101-H	464	0.550	0.630	1.180	2,225	2,072	111.9
85/05/08	101-H	466	0.460	0.640	1.090	2,096	1,995	112.7
85/06/24	101-H	491	0.428	0.584	1.012	2,280	2,116	99.8
85/06/25	101-H	493	0.338	0.440	0.778	2,019	1,893	109.9
85/06/26	101-H	495	0.436	0.556	0.993	1,847	1,696	106.5
85/07/08	101-H	498	0.631	0.643	1.274	2,290	2,104	107.4
85/07/09	101-H	500	0.483	0.523	1.007	2,193	2,000	110.6
85/07/10	101-H	502	0.311	0.484	0.795	1,948	1,760	114.8
85/08/12	101-H	516	0.331	0.420	0.751	1,944	1,784	102.0
85/08/13	101-H	518	0.275	0.425	0.700	1,858	1,713	102.8
85/08/14	101-H	520	0.363	0.307	0.671	1,936	1,788	106.0

Table A-1. ALUMAX ROOF MONITOR DATA.

103-G ROOF MONITOR RESULTS 1985

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
85/01/14	103-G	411	0.160	0.140	0.300	1,630	1,602	103.2
85/01/15	103-G	413	0.170	0.180	0.350	1,582	1,563	108.1
85/01/16	103-G	415	0.270	0.320	0.580	1,361	1,354	107.5
85/02/04	103-G	420	0.410	0.420	0.820	2,304	2,277	102.3
85/02/05	103-G	422	0.200	0.410	0.610	2,049	2,030	103.6
85/02/06	103-G	424	0.230	0.490	0.720	2,077	1,983	108.8
85/03/11	103-G	441	0.460	0.380	0.830	1,975	1,940	94.9
85/03/12	103-G	443	0.270	0.480	0.750	1,707	1,635	109.3
85/03/13	103-G	445	0.290	0.320	0.610	1,625	1,580	98.4
85/04/01	103-G	449	0.360	0.150	0.510	1,582	1,538	108.8
85/04/02	103-G	451	0.400	0.490	0.890	1,508	1,481	89.9
85/04/03	103-G	453	0.260	0.260	0.510	1,633	1,603	105.3
85/05/13	103-G	467	0.690	0.520	1.210	1,737	1,625	106.0
85/05/14	103-G	469	0.600	0.440	1.040	1,956	1,819	97.3
85/05/15	103-G	471	0.470	0.670	1.140	2,424	2,257	98.5
85/06/03	103-G	479	0.370	0.550	0.930	2,023	1,846	107.7
85/06/04	103-G	481	0.460	0.480	0.940	1,963	1,791	110.1
85/06/05	103-G	483	0.440	0.410	0.850	2,176	2,007	106.3
85/07/15	103-G	503	0.408	0.446	0.854	1,559	1,440	112.8
85/07/16	103-G	505	0.298	0.730	1.028	1,624	1,491	105.2
85/08/05	103-G	509	0.436	0.437	0.873	1,656	1,565	101.3
85/08/06	103-G	511	0.629	0.346	0.975	1,837	1,726	102.6
85/08/07	103-G	513	0.350	0.573	0.923	2,054	1,918	100.3

Table A-1. ALUMAX ROOF MONITOR DATA.

103-H ROOF MONITOR RESULTS 1985

DATE	LOC	TEST#	P F LB	G F LB	T F LB	ACFM	SCFM	% ISO
85/01/14	103-H	412	0.250	0.1900	0.450	1,079	1,065	103.4
85/01/15	103-H	414	0.230	0.2600	0.480	1,265	1,254	106.3
85/01/16	103-H	416	0.150	0.1800	0.330	1,202	1,209	94.0
85/02/04	103-H	421	0.410	0.3300	0.730	2,430	2,451	100.1
85/02/05	103-H	423	0.260	0.3700	0.630	1,526	1,531	112.8
85/02/06	103-H	425	0.220	0.3300	0.550	1,468	1,435	103.4
85/03/11	103-H	442	0.510	0.3100	0.820	1,803	1,761	95.3
85/03/12	103-H	444	0.490	0.6500	1.140	1,646	1,552	104.1
85/03/13	103-H	446	0.510	0.3300	0.830	1,576	1,520	96.4
85/04/01	103-H	450	0.390	0.4400	0.820	1,695	1,677	104.0
85/04/02	103-H	452	0.330	0.3700	0.700	2,528	2,550	98.0
85/04/03	103-H	454	0.440	0.4200	0.860	1,513	1,480	106.2
85/05/13	103-H	468	0.140	0.5600	0.700	2,252	2,104	104.5
85/05/14	103-H	470	0.430	0.5600	0.990	2,222	2,054	102.8
85/05/15	103-H	472	0.440	0.5800	1.020	2,208	2,046	111.2
85/06/24	103-H	492	0.501	0.6150	1.116	2,440	2,257	96.7
85/06/25	103-H	494	0.323	0.4190	0.742	1,924	1,762	102.0
85/06/26	103-H	496	0.355	0.6440	0.998	1,790	1,622	97.4
85/07/15	103-H	504	0.220	0.5680	0.788	2,144	1,964	96.2
85/07/16	103-H	506	0.520	0.5611	1.081	2,234	2,042	108.4
85/08/05	103-H	510	0.454	0.4290	0.883	2,348	2,198	102.4
85/08/06	103-H	512	0.482	0.5600	1.040	2,210	2,063	98.5
85/08/07	103-H	514	0.340	0.5020	0.842	2,242	2,070	104.0

TABLE . DRY SCRUBBER
EMISSIONS SUMMARY 161 EAST.

DATE	LOCATION	TEST#	AL/P/D	% ISO	T F LB/T
81/01/19	161-E	015	2,932.7		0.018
		016	2,932.7		0.024
81/01/20	161-E	017	2,935.0		0.018
81/02/17	161-E	020	2,913.4	106.4	0.029
		021	2,913.4	101.3	0.027
		022	2,913.4	107.1	0.049
81/03/10	161-E	007	2,920.0	98.8	0.014
81/03/11	161-E	008	2,924.3	105.3	0.020
		009	2,924.3	97.1	0.018
81/04/06	161-E	013	2,952.8	94.7	0.030
		014	2,952.8	94.1	0.057
		015	2,952.8	99.4	0.020
81/05/12	161-E	040	2,876.4	96.7	0.035
81/05/13	161-E	041	2,840.9	104.1	0.155
		042	2,840.9	104.4	0.056
81/06/08	161-E	065	2,957.1	105.6	0.093
		066	2,957.1	91.5	0.058
		067	2,957.1	103.8	0.070
81/07/07	161-E	092	2,980.8	112.4	0.074
		093	2,980.8	98.2	0.058
81/07/08	161-E	094	2,980.2	103.2	0.055
81/08/11	161-E	119	2,863.6	98.6	0.107
		120	2,863.6	108.7	0.067
81/08/12	161-E	121	2,860.0	94.0	0.069
81/09/01	161-E	135	2,860.2	102.3	0.079
81/09/02	161-E	137	2,828.5	92.4	0.068
		138	2,822.5	93.8	0.064
81/10/05	161-E	154	2,869.0	114.6	0.047
81/10/06	161-E	156	2,870.4	97.9	0.038
		157	2,870.4	115.9	0.040
81/11/10	161-E	180	2,882.9	82.7	0.026
		178	2,882.9	105.7	0.044
		179	2,882.9	87.0	0.040
81/12/01	161-E	191	3,046.6	96.1	0.071
81/12/02	161-E	192	3,045.3	100.7	0.079
		193	3,045.3	102.2	0.059
82/01/12	161-E	219	3,018.0	100.9	0.017
		220	3,018.1	98.3	0.020
82/01/13	161-E	221	3,015.8	101.2	0.019
82/02/03	161-E	225	3,036.1	98.5	0.048
		226	3,036.1	96.4	0.034
		227	3,038.0	105.4	0.037

TABLE A-2. DRY SCRUBBER
EMISSIONS SUMMARY 161 EAST.

DATE	LOCATION	TEST#	AL/P/D	% ISO	T F LB/T
82/03/09	161-E	243	2,968.8	101.7	0.013
		244	2,968.8	96.8	0.015
82/03/10	161-E	246	2,962.7	100.8	0.017
82/04/06	161-E	257	3,029.0	100.1	0.032
82/04/07	161-E	258	3,030.4	108.3	0.022
		259	3,030.4	101.1	0.037
82/04/27	161-E	275	2,997.9	117.4	0.048
		276	2,997.9	108.4	0.049
82/04/28	161-E	277	3,000.5	105.7	0.032
83/09/22	161-E	158	3,050.4	106.8	0.061
		159	3,050.4	103.4	0.045
83/09/23	161-E	160	3,055.8	102.6	0.055
84/10/08	161-E	365	3,097.2	108.4	0.020
84/10/09	161-E	366	3,091.5	110.1	0.018
84/10/12	161-E	367	3,094.1	116.1	0.133
	AVERAGE:		2,958.2	101.9	0.046
	COUNT:	57			

TABLE A-2.
DRY SCRUBBER
EMISSIONS SUMMARY 161 WEST.

DATE	LOCATION	TEST#	AL/P/D	% ISO	T F LB/T
81/01/12	161-W	009	2,929.4		0.028
		010	2,994.4		0.032
81/01/13	161-W	011	2,911.8		0.114
81/02/02	161-W	023	2,985.8	90.4	0.021
81/02/03	161-W	024	2,982.9	107.8	0.018
		025	2,982.9	94.8	0.021
81/03/09	161-W	005	2,917.8	100.4	0.205
		006	2,917.8	105.1	0.023
		004	2,917.3	101.0	0.028
81/03/31	161-W	010	2,956.5	108.8	0.021
		011	2,956.5	102.3	0.020
81/04/01	161-W	012	2,956.5	96.4	0.015
81/05/11	161-W	037	2,864.8	93.9	0.052
		038	2,864.8	102.6	0.370
		039	2,864.8	100.7	0.035
81/06/09	161-W	068	2,980.0	101.7	0.364
		069	2,980.0	100.7	0.181
		070	2,980.0	94.1	0.243
81/07/08	161-W	095	2,980.8	114.5	0.035
81/07/09	161-W	096	2,975.5	109.4	0.100
		097	2,975.5	110.0	0.083
81/08/10	161-W	116	2,874.8	105.2	0.070
		117	2,874.8	112.7	0.081
		118	2,874.8	102.6	0.070
81/08/31	161-W	132	2,828.3	107.3	0.070
		133	2,828.3	89.8	0.107
		134	2,828.3	89.4	0.085
81/10/07	161-W	158	2,870.2	112.5	0.087
		159	2,870.2	99.5	0.039
81/10/08	161-W	160	2,877.9	99.0	0.040
81/11/09	161-W	177	2,887.3	86.6	0.053
		175	2,887.3	98.1	0.039
		176	2,887.3	87.9	0.060
81/11/30	161-W	188	3,048.9	104.9	0.047
		189	3,048.9	102.7	0.039
		190	3,048.9	96.1	0.037
82/01/11	161-W	216	3,017.4	91.8	0.058
		217	3,017.4	91.5	0.096
		218	3,017.4	100.9	0.072
82/02/01	161-W	222	3,032.1	91.0	0.273
		223	3,032.1	103.7	0.172
		224	3,032.1	91.3	0.165

Table A-2. DRY SCRUBBER
EMISSIONS SUMMARY 161 WEST.

DATE	LOCATION	TEST#	AL/P/D	% ISO	T F LB/T
82/03/08	161-W	240	2,931.7	88.8	0.020
		241	2,931.7	98.2	0.024
		242	2,931.7	114.4	0.019
82/04/05	161-W	254	3,026.6	104.1	0.041
		255	3,026.6	105.2	0.051
		256	3,026.6	113.3	0.063
82/04/26	161-W	272	2,996.1	112.2	0.086
		273	2,996.1	104.0	0.212
		274	2,996.1	109.5	0.111
83/09/20	161-W	155	3,055.7	106.0	0.225
		156	3,055.7	119.2	0.093
83/09/21	161-W	157	3,054.9	110.9	0.087
84/10/22	161-W	368	3,096.1	103.2	0.050
		369	3,096.1	107.0	0.073
		370	3,096.1	112.1	0.058
	AVERAGE:		2,962.7	101.9	0.087
	COUNT:	57			

TABLE A-2. DRY SCRUBBER
EMISSIONS SUMMARY 162 EAST.

DATE	LOCATION	TEST#	AL/P/D	% ISO	T F LB/T
81/02/23	162-E	025	2,990.8	102.0	0.024
		023	2,990.8	103.4	0.151
		024	2,990.8	102.9	0.064
81/04/20	162-E	019	2,920.9	104.7	0.042
		020	2,920.9	97.9	0.038
		021	2,920.9	101.0	0.034
81/05/26	162-E	053	2,957.9	100.8	0.181
		054	2,957.9	100.3	0.125
		055	2,957.9	101.0	0.190
81/06/02	162-E	062	2,971.2	110.1	0.214
		063	2,971.2	106.9	0.151
81/06/03	162-E	064	2,971.2	109.3	0.122
81/07/28	162-E	107	3,001.7	108.1	0.109
		108	3,001.7	103.9	0.096
81/07/29	162-E	109	3,001.6	107.5	0.095
81/08/04	162-E	110	2,997.1	114.3	0.368
		111	2,997.1	108.3	0.207
81/08/11	162-E	112	2,997.1	96.6	0.084
81/09/09	162-E	142	2,838.5	108.3	0.210
81/09/10	162-E	143	2,844.2	100.9	0.209
		144	2,844.2	98.1	0.187
81/10/14	162-E	164	3,012.0	96.8	0.145
		165	3,012.2	95.5	0.122
81/10/15	162-E	166	3,012.2	99.4	0.105
81/11/04	162-E	172	2,946.6	90.0	0.140
		173	2,946.6	100.9	0.095
81/11/05	162-E	174	2,945.7	91.3	0.110
81/12/08	162-E	197	3,026.8	100.1	0.051
		198	3,026.8	102.4	0.048
81/12/09	162-E	199	3,023.2	101.8	0.045
82/01/06	162-E	213	2,936.4	97.1	0.052
		214	2,996.4	99.3	0.058
		215	2,996.4	96.5	0.070
82/02/09	162-E	231	2,987.4	101.2	0.080
		232	2,987.4	101.8	0.084
		233	2,987.4	100.2	0.141
82/03/02	162-E	237	2,956.7	109.6	0.039
		238	2,956.7	97.2	0.055
82/03/03	162-E	239	2,960.8	102.6	0.055
82/04/13	162-E	263	3,017.9	108.5	0.083
82/04/14	162-E	264	3,022.2	101.6	0.064
		265	3,022.2	112.9	0.059

TABLE A-2. DRY SCRUBBER
EMISSIONS SUMMARY 162 EAST.

DATE	LOCATION	TEST#	AL/P/D	% ISO	T F LB/T
82/04/21	162-E	269	2,998.9	104.7	0.145
		270	2,998.9	113.4	0.080
		271	2,997.5	104.5	0.118
83/10/25	162-E	182	3,070.3	108.6	0.048
		183	3,070.3	110.8	0.046
83/10/26	162-E	184	3,075.8	109.4	0.039
84/09/17	162-E	359	3,077.5	110.3	0.106
84/09/18	162-E	360	3,080.4	107.1	0.076
84/09/19	162-E	361	3,085.1	113.4	0.048
	AVERAGE:		2,985.8	103.4	0.104
	COUNT:	51			

TABLE A-2. DRY SCRUBBER

EMISSIONS SUMMARY 162 WEST.

DATE	LOCATION	TEST#	AL/P/D	% ISO	T F LB/T
81/03/02	162-W	002	2,955.5	101.4	0.021
		003	2,955.5	102.1	0.016
		001	2,955.5	101.3	0.025
81/04/13	162-W	016	2,904.7	112.0	0.033
		017	2,904.7	107.2	0.034
		018	2,899.2	110.0	0.101
81/05/27	162-W	056	3,003.9	105.6	0.084
		057	3,016.9	91.8	0.081
81/05/28	162-W	058	3,016.9	100.9	0.108
81/06/01	162-W	101	2,981.7	106.9	0.113
		102	2,981.7	110.0	0.247
		103	2,981.7	104.7	0.123
81/07/27	162-W	104	3,004.4	107.4	0.053
		105	3,004.4	98.2	0.084
		106	3,004.4	109.7	0.060
81/08/03	162-W	114	2,995.0	104.8	0.056
		115	2,991.5	93.8	0.051
		113	2,995.0	103.9	0.070
81/09/08	162-W	139	2,841.7	106.6	0.103
		140	2,841.7	90.6	0.071
		141	2,841.7	100.8	0.065
81/10/12	162-W	161	3,013.7	90.8	0.248
		162	3,013.7	97.6	0.075
		163	3,013.7	90.4	0.056
81/11/02	162-W	168	2,949.6	96.5	0.056
81/11/03	162-W	170	2,948.1	90.0	0.045
		169	2,949.6	96.7	0.047
81/12/07	162-W	194	3,027.2	102.3	0.017
		195	3,027.2	101.9	0.040
		196	3,027.2	93.0	0.027
82/01/04	162-W	210	2,934.8	102.4	0.120
82/01/05	162-W	211	2,994.3	90.9	0.146
		212	2,994.8	101.4	0.075
82/02/08	162-W	228	2,987.6	86.3	0.039
		229	2,987.6	98.4	0.052
		230	2,987.6	99.7	0.044
82/03/01	162-W	234	3,958.2	106.0	0.029
		235	2,958.2	101.8	0.035
		236	2,958.2	104.9	0.023
82/04/12	162-W	260	3,014.3	111.0	0.036
		261	3,014.3	100.8	0.062
		262	3,014.3	108.8	0.031

TABLE A-2. DRY SCRUBBER
EMISSIONS SUMMARY 162 WEST.

DATE	LOCATION	TEST#	AL/P/D	% ISO	T F LB/T
82/04/20	162-W	266	2,997.5	104.8	0.043
		267	2,997.5	95.3	0.060
		268	2,997.5	112.6	0.045
83/10/24	162-W	179	3,071.0	110.0	0.044
		180	3,041.0	104.3	0.061
		181	3,071.0	112.0	0.037
84/09/24	162-W	362	3,098.3	109.9	0.063
84/09/25	162-W	363	3,103.2	112.2	0.040
84/09/27	162-W	364	3,101.5	114.0	0.032
	AVERAGE:		3,006.4	102.2	0.065
	COUNT:	51			

TABLE A-3a. ROOF MONITOR 101G STATISTICS BY YEAR.

THE FOLLOWING RESULTS ARE FOR:
RM# = 101G
YEAR = 81.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.60530	0.05450
MAXIMUM	1.02000	0.25330
RANGE	0.41470	0.19880
MEAN	0.81795	0.13691
STANDARD DEV	0.12401	0.06824
SKEWNESS	0.18829	0.40106
KURTOSIS	-0.72386	-1.26730

THE FOLLOWING RESULTS ARE FOR:
RM# = 101G
YEAR = 82.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.43930	0.01970
MAXIMUM	0.97000	0.24250
RANGE	0.53070	0.22280
MEAN	0.70387	0.12957
STANDARD DEV	0.14012	0.05856
SKEWNESS	-0.10351	0.01948
KURTOSIS	0.00133	-0.12057

THE FOLLOWING RESULTS ARE FOR:
RM# = 101G
YEAR = 83.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.48330	0.04510
MAXIMUM	1.15330	0.31190
RANGE	0.67000	0.26680
MEAN	0.79333	0.15545
STANDARD DEV	0.19334	0.09007
SKEWNESS	0.20463	0.79149
KURTOSIS	-0.59513	-0.78111

THE FOLLOWING RESULTS ARE FOR:
RM# = 101G
YEAR = 84.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.53670	0.03510
MAXIMUM	0.99000	0.30730
RANGE	0.45330	0.27220
MEAN	0.77195	0.11210
STANDARD DEV	0.11849	0.06935
SKEWNESS	-0.08179	1.89794
KURTOSIS	-0.05152	3.46135

THE FOLLOWING RESULTS ARE FOR:
RM# = 101G
YEAR = 85.000

TOTAL OBSERVATIONS: 3

	XBAR	SX
N OF CASES	3	3
MINIMUM	0.59670	0.06160
MAXIMUM	0.77330	0.29910
RANGE	0.17660	0.23750
MEAN	0.65943	0.15697
STANDARD DEV	0.09878	0.12547
SKEWNESS	0.69615	0.58963
KURTOSIS	-1.50000	-1.50000

TABLE A-3b ROOF MONITOR 101H STATISTICS BY YEAR.

THE FOLLOWING RESULTS ARE FOR:
RM# = 101H
YEAR = 81.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.67400	0.10360
MAXIMUM	1.28500	0.32340
RANGE	0.61100	0.21980
MEAN	0.88616	0.17450
STANDARD DEV	0.17799	0.07781
SKEWNESS	0.97064	1.08287
KURTOSIS	0.28560	-0.16844

THE FOLLOWING RESULTS ARE FOR:
RM# = 101H
YEAR = 82.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.56600	0.01990
MAXIMUM	1.10330	0.27780
RANGE	0.53730	0.25790
MEAN	0.85497	0.12062
STANDARD DEV	0.13798	0.07544
SKEWNESS	-0.13451	0.48347
KURTOSIS	0.27422	-0.24193

THE FOLLOWING RESULTS ARE FOR:
RM# = 101H
YEAR = 83.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.68670	0..05200
MAXIMUM	1.04330	0.29310
RANGE	0.35660	0.24110
MEAN	0.85750	0.13608
STANDARD DEV	0.10376	0.06526
SKEWNESS	0.09260	1.03494
KURTOSIS	-0.65552	0.86419

THE FOLLOWING RESULTS ARE FOR:
RM# = 101H
YEAR = 84.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.74670	0.05690
MAXIMUM	1.00670	0.32600
RANGE	0.26000	0.26910
MEAN	0.87388	0.20784
STANDARD DEV	0.09457	0.08325
SKEWNESS	0.20677	-0.30967
KURTOSIS	-1.42490	-1.01287

THE FOLLOWING RESULTS ARE FOR:
RM# = 101H
YEAR = 85.000

TOTAL OBSERVATIONS: 3

	XBAR	SX
N OF CASES	3	3
MINIMUM	0.70330	0.26640
MAXIMUM	1.05670	0.32520
RANGE	0.35340	0.05880
MEAN	0.87367	0.28753
STANDARD DEV	0.17704	0.03270
SKEWNESS	0.13077	0.69140
KURTOSIS	-1.50000	-1.50000

TABLE A-3c. ROOF MONITOR 103G STATISTICS BY YEAR.

THE FOLLOWING RESULTS ARE FOR:
RM# = 103G
YEAR = 81.000

TOTAL OBSERVATIONS: 10

	XBAR	SX
N OF CASES	10	10
MINIMUM	0.53100	0.04590
MAXIMUM	0.94050	0.24340
RANGE	0.40950	0.19750
MEAN	0.68908	0.12434
STANDARD DEV	0.14487	0.06942
SKEWNESS	0.46481	0.71031
KURTOSIS	-1.18160	-1.03369

THE FOLLOWING RESULTS ARE FOR:
RM# = 103G
YEAR = 82.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.33330	0.02520
MAXIMUM	0.92000	0.44030
RANGE	0.58670	0.41510
MEAN	0.69922	0.13966
STANDARD DEV	0.18343	0.12858
SKEWNESS	-0.55016	1.22035
KURTOSIS	-0.62370	0.55509

THE FOLLOWING RESULTS ARE FOR:
RM# = 103G
YEAR = 83.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.43330	0.01530
MAXIMUM	1.12000	0.29140
RANGE	0.68670	0.27610
MEAN	0.79500	0.13131
STANDARD DEV	0.22934	0.09154
SKEWNESS	-0.04009	0.34984
KURTOSIS	-1.20337	-1.11994

THE FOLLOWING RESULTS ARE FOR:
RM# = 103G
YEAR = 84.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.55000	0.01730
MAXIMUM	0.98000	0.18330
RANGE	0.43000	0.16600
MEAN	0.77305	0.09673
STANDARD DEV	0.14888	0.06331
SKEWNESS	0.15177	0.02243
KURTOSIS	-1.36177	-1.53934

THE FOLLOWING RESULTS ARE FOR:
RM# = 103G
YEAR = 85.000

TOTAL OBSERVATIONS: 2

	XBAR	SX
N OF CASES	2	2
MINIMUM	0.41000	0.10510
MAXIMUM	0.71670	0.14930
RANGE	0.30670	0.04420
MEAN	0.56335	0.12720
STANDARD DEV	0.21687	0.03125
SKEWNESS	0.00000	0.00000
KURTOSIS	-2.00000	-2.00000

TABLE A-3d ROOF MONITOR 103H STATISTICS BY YEAR.

THE FOLLOWING RESULTS ARE FOR:
RM# = 103H
YEAR = 81.000

TOTAL OBSERVATIONS: 10

	XBAR	SX
N OF CASES	10	10
MINIMUM	0.66800	0.03540
MAXIMUM	1.29000	0.26260
RANGE	0.62200	0.22720
MEAN	0.98488	0.12847
STANDARD DEV	0.18449	0.08746
SKEWNESS	-0.12938	0.41515
KURTOSIS	-0.75163	-1.15534

THE FOLLOWING RESULTS ARE FOR:
RM# = 103H
YEAR = 82.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.42000	0.08620
MAXIMUM	1.18330	0.21950
RANGE	0.76330	0.13330
MEAN	0.84922	0.17530
STANDARD DEV	0.21083	0.04256
SKEWNESS	-0.35875	-0.77000
KURTOSIS	-0.16665	-0.47223

THE FOLLOWING RESULTS ARE FOR:
RM# = 103H
YEAR = 83.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.37000	0.04730
MAXIMUM	1.10670	0.52920
RANGE	0.73670	0.48190
MEAN	0.79778	0.15298
STANDARD DEV	0.18536	0.12826
SKEWNESS	-0.66855	2.26157
KURTOSIS	0.72182	4.45037

THE FOLLOWING RESULTS ARE FOR:
RM# = 103H
YEAR = 84.000

TOTAL OBSERVATIONS: 12

	XBAR	SX
N OF CASES	12	12
MINIMUM	0.59670	0.06430
MAXIMUM	1.31330	0.35160
RANGE	0.71660	0.28730
MEAN	0.85056	0.16978
STANDARD DEV	0.18036	0.07395
SKEWNESS	1.23816	1.15325
KURTOSIS	1.82144	1.21949

THE FOLLOWING RESULTS ARE FOR:
RM# = 103H
YEAR = 85.000

TOTAL OBSERVATIONS: 2

	XBAR	SX
N OF CASES	2	2
MINIMUM	0.42000	0.07940
MAXIMUM	0.63670	0.09020
RANGE	0.21670	0.01080
MEAN	0.52835	0.08480
STANDARD DEV	0.15323	0.00764
SKEWNESS	0.00000	0.00000
KURTOSIS	-2.00000	-2.00000

TABLE A-4. ANALYSIS OF VARIANCE WITH MONITORS AS TREATMENTS.

ANALYSIS OF VARIANCE WITH MONITORS AS TREATMENTS.

DEP VAR: XBAR N: 220 MULTIPLE R: .319 SQUARED MULTIPLE R: .102

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
MONITOR	0.73297	3	0.24432	8.152	.000
ERROR	6.47392	216	0.02997		

TABLE A-5. COMPARISON OF ROOF MONITOR ANNUAL MEANS.

RMS	$\bar{X}_i$	$s_{\bar{x}_i}$	n	i	RMS	$\bar{X}$
101G	0.76001	0.14596	56	4	101H	0.86961
101H	0.86961	0.13207	56	3	103H	0.85761
103G	0.74987	0.13661	54	2	101G	0.76001
103H	0.85761	0.15511	54	1	103G	0.74987

DIFFERENCES

Pair	d_i
4-1	0.11974 **
4-2	0.10960 **
4-3	0.01200
3-1	0.10774 **
3-2	0.09760 **
2-1	0.01014 *

Pooled variance, $s^2 = 0.029$ (from ANOVA)
at the 5% level of significance (*)

$$lsd(0.05) = 1.972\sqrt{\frac{0.029}{55}} = 0.045$$

at the 1% level of significance (**)

$$lsd(0.01) = 2.601\sqrt{\frac{0.029}{55}} = 0.060$$

Roof monitor Paired Comparisons.

	103H	103G	101H
101G	0.09760 **	0.01014	0.10960 **
101H	0.01200	0.11974 **	
103G	0.10774 **		

The double asterisk indicates the paired differences which are significantly different from zero at less than the 1% level of significance, e.g. the pair 103H - 101G is significantly different.

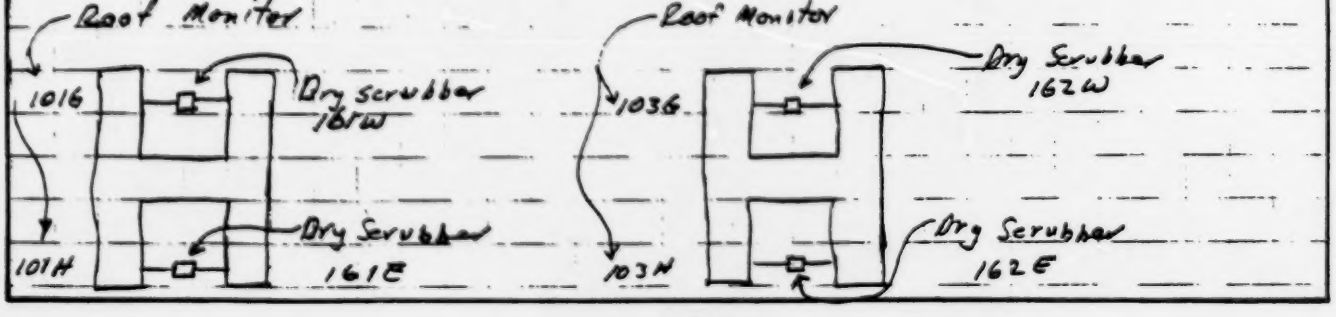


TABLE A-6. ANALYSIS OF VARIANCE WITH DRY SCRUBBERS AS TREATMENT.

ANALYSIS OF VARIANCE WITH DRY SCRUBBER AS TREATMENTS.

DEP VAR: XBAR N: 72 MULTIPLE R: .418 SQUARED MULTIPLE R: .175

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
DSCRUB	0.031212	3	0.010404	4.796	.004
ERROR	0.147514	68	0.002169		

TABLE A-7. LEAST SIGNIFICANT DIFFERENCE - DRY SCRUBBER MEANS.

DS	XBAR	n
161W	0.08736	19
161E	0.04634	19
162W	0.06524	17
162E	0.10055	17

SORTED

Rank	DS	XBAR
1	162E	0.10055
3	161W	0.08736
2	162W	0.06524
1	161E	0.04634

Rank pair	Δ_{ij}	Significance
4-1	0.05421	**
4-2	0.03531	*
4-3	0.01319	
3-1	0.04102	*
3-2	0.02212	
2-1	0.01890	

Dry scrubber

$s^2 = 0.002169$ from ANOVA. with

$df = 68$

$t_{0.025,60} = 1.996$

$t_{0.005,60} = 2.652$

19/19 comparison

$lsd\ (0.05) = 1.996 \sqrt{\frac{2 \times 0.002169}{19}}$

$= 0.03016$

$lsd\ 0.01 = 2.652$

$= 0.04236$

19/17 Comparison

$lsd\ (0.05) = 1.996 \sqrt{0.002169\left(\frac{1}{19} + \frac{1}{17}\right)}$

$= 0.03103$

19/17

$lsd\ (0.01) = 0.04123$

17/17 Comparison

17/17

$lsd\ (0.05) = 1.996 \sqrt{\frac{0.002169\ (2)}{17}}$

$= 0.03188$

$lsd\ (0.01) = 0.04236$

Paired Difference Table -- Dry Scrubber Mean Emissions

	161E	162W	161W
162E	0.05421 **	0.03531 *	0.01319
161W	0.04102 *	0.02212	
162W	0.01890		

** Highly Significant at the 0.01 level of significance (probability = 0.01)

* Significant at the 0.05 level of significance (probability = 0.95)

TABLE A-8a. ROOF MONITOR DATA KOLMOGOROV D STATISTIC.

UNIVARIATE

VARIABLE=XBAR

MOMENTS

N	220	SUM WGTS	220
MEAN	0.809367	SUM	178.061
STD DEV	0.174152	VARIANCE	0.0303288
SKEWNESS	0.0195071	KURTOSIS	0.249447
USS	150.759	CSS	6.642
CV	21.517	STD MEAN	0.0117413
T:MEAN=0	68.9334	PROB>|T|	0.0001
SGN RANK	12155	PROB>|S|	0.0001
NUM ^= 0	220		
D:NORMAL	0.0317748	PROB>D	>0.15

QUANTILES(DEF=4)

100% MAX	1.3133	99%	1.28895
75% Q3	0.92	95%	1.1162
50% MED	0.81335	90%	1.02477
25% Q1	0.700825	10%	0.59364
0% MIN	0.3333	5%	0.5177
		1%	0.3784
RANGE	0.98		
Q3-Q1	0.219175		
MODE	0.7167		

VARIABLE=LXBAR

MOMENTS

N	220	SUM WGTS	220
MEAN	-0.236448	SUM	-52.0187
STD DEV	0.230251	VARIANCE	0.0530154
SKEWNESS	-0.781481	KURTOSIS	1.18344
USS	23.9101	CSS	11.6104
CV	-97.3789	STD MEAN	0.0155235
T:MEAN=0	-15.2316	PROB>|T|	0.0001
SGN RANK	-10853	PROB>|S|	0.0001
NUM ^= 0	220		
D:NORMAL	0.0644181	PROB>D	0.024

QUANTILES(DEF=4)

100% MAX	0.272543	99%	0.253827
75% Q3	-0.0833816	95%	0.109928
50% MED	-0.206602	90%	0.024467
25% Q1	-0.355499	10%	-0.521484
0% MIN	-1.09871	5%	-0.658376
		1%	-0.972695
RANGE	1.37126		
Q3-Q1	0.272118		
MODE	-0.333098		

TABLE A-8b. ROOF MONITOR 101G. KOLMOGOROV D STATISTIC.

MON=101G

UNIVARIATE

VARIABLE=LXBAR

MOMENTS

N	56	SUM WGTS	56
MEAN	-0.292971	SUM	-16.4064
STD DEV	0.19607	VARIANCE	0.0384436
SKEWNESS	-0.320428	KURTOSIS	0.270236
USS	6.92101	CSS	2.1144
CV	-66.9248	STD MEAN	0.026201
T:MEAN=0	-11.1817	PROB>|T|	0.0001
SGN RANK	-779	PROB>|S|	0.0001
NUM ^= 0	56		
D:NORMAL	0.0599727	PROB>D	>0.15

QUANTILES(DEF=4)

100% MAX	0.142627	99%	0.142627
75% Q3	-0.165878	95%	0.021266
50% MED	-0.29863	90%	-0.0243368
25% Q1	-0.406096	10%	-0.54079
0% MIN	-0.822573	5%	-0.669823
		1%	-0.822573
RANGE	0.9652		
Q3-Q1	0.240218		
MODE	-0.333098		

MON=101G

UNIVARIATE

VARIABLE=XBAR

MOMENTS

N	56	SUM WGTS	56
MEAN	0.759979	SUM	42.5588
STD DEV	0.145988	VARIANCE	0.0213125
SKEWNESS	0.26947	KURTOSIS	0.130776
USS	33.516	CSS	1.17219
CV	19.2095	STD MEAN	0.0195085
T:MEAN=0	38.9564	PROB>|T|	0.0001
SGN RANK	798	PROB>|S|	0.0001
NUM ^= 0	56		
D:NORMAL	0.0625351	PROB>D	>0.15

QUANTILES(DEF=4)

100% MAX	1.1533	99%	1.1533
75% Q3	0.84715	95%	1.0215
50% MED	0.74185	90%	0.976
25% Q1	0.66625	10%	0.58269
0% MIN	0.4393	5%	0.511945
		1%	0.4393
RANGE	0.714		
Q3-Q1	0.1809		
MODE	0.7167		

TABLE A-8c. ROOF MONITOR 101H. KOLMOGOROV D STATISTIC.

MON=101H

UNIVARIATE

VARIABLE=XBAR

MOMENTS

N	56	SUM WGTS	56
MEAN	0.869611	SUM	48.6982
STD DEV	0.132073	VARIANCE	0.0174432
SKEWNESS	0.525695	KURTOSIS	0.780922
USS	43.3079	CSS	0.959377
CV	15.1876	STD MEAN	0.017649
T:MEAN=0	49.2726	PROB>|T|	0.0001
SGN RANK	798	PROB>|S|	0.0001
NUM ^= 0	56		
D:NORMAL	0.0716823	PROB>D	>0.15

QUANTILES(DEF=4)

100% MAX	1.285	99%	1.285
75% Q3	0.965	95%	1.1078
50% MED	0.85165	90%	1.04432
25% Q1	0.78415	10%	0.70231
0% MIN	0.566	5%	0.681905
		1%	0.566
RANGE	0.719		
Q3-Q1	0.18085		
MODE	0.7833		

MON=101H

UNIVARIATE

VARIABLE=LXBAR

MOMENTS

N	56	SUM WGTS	56
MEAN	-0.150875	SUM	-8.44898
STD DEV	0.150734	VARIANCE	0.0227206
SKEWNESS	0.00353465	KURTOSIS	0.431585
USS	2.52437	CSS	1.24963
CV	-99.9065	STD MEAN	0.0201426
T:MEAN=0	-7.49032	PROB>|T|	0.0001
SGN RANK	-667	PROB>|S|	0.0001
NUM ^= 0	56		
D:NORMAL	0.0535399	PROB>D	>0.15

QUANTILES(DEF=4)

100% MAX	0.250759	99%	0.250759
75% Q3	-0.0356677	95%	0.10233
50% MED	-0.160581	90%	0.0433648
25% Q1	-0.243157	10%	-0.353383
0% MIN	-0.569161	5%	-0.382877
		1%	-0.569161
RANGE	0.81992		
Q3-Q1	0.207489		
MODE	-0.24424		

TABLE A-8d. ROOF MONITOR 103G KOLMOGOROV D STATISTIC.

MON=103G

UNIVARIATE

VARIABLE=XBAR

MOMENTS

N	54	SUM WGTS	54
MEAN	0.749867	SUM	40.4928
STD DEV	0.186611	VARIANCE	0.0348237
SKEWNESS	0.0265797	KURTOSIS	-0.546949
USS	32.2099	CSS	1.84566
CV	24.8859	STD MEAN	0.0253945
T:MEAN=0	29.5286	PROB>|T|	0.0001
SGN RANK	742.5	PROB>|S|	0.0001
NUM ^= 0	54		
D:NORMAL	0.0857499	PROB>D	>0.15

QUANTILES(DEF=4)

100% MAX	1.13	99%	1.13
75% Q3	0.910025	95%	1.11752
50% MED	0.73165	90%	0.96665
25% Q1	0.598325	10%	0.51715
0% MIN	0.3333	5%	0.427475
		1%	0.3333
RANGE	0.7967		
Q3-Q1	0.3117		
MODE	0.73		

MON=103G

UNIVARIATE

VARIABLE=LXBAR

MOMENTS

N	54	SUM WGTS	54
MEAN	-0.320701	SUM	-17.3178
STD DEV	0.265456	VARIANCE	0.0704667
SKEWNESS	-0.599186	KURTOSIS	0.223004
USS	9.28858	CSS	3.73473
CV	-82.7736	STD MEAN	0.0361239
T:MEAN=0	-8.87779	PROB>|T|	0.0001
SGN RANK	-695.5	PROB>|S|	0.0001
NUM ^= 0	54		
D:NORMAL	0.0897283	PROB>D	>0.15

QUANTILES(DEF=4)

100% MAX	0.122218	99%	0.122218
75% Q3	-0.0943031	95%	0.111116
50% MED	-0.312456	90%	-0.0340146
25% Q1	-0.513633	10%	-0.659781
0% MIN	-1.09871	5%	-0.850143
		1%	-1.09871
RANGE	1.22093		
Q3-Q1	0.41933		
MODE	-0.314711		

TABLE A-8c. ROOF MONITOR 103H KOLMOGOROV D STATISTIC.

MON=103H

UNIVARIATE

VARIABLE=XBAR

MOMENTS

N	54	SUM WGTS	54
MEAN	0.857611	SUM	46.311
STD DEV	0.194649	VARIANCE	0.0378884
SKEWNESS	-0.149388	KURTOSIS	0.64548
USS	41.7249	CSS	2.00808
CV	22.6967	STD MEAN	0.0264884
T:MEAN=0	32.3768	PROB>|T|	0.0001
SGN RANK	742.5	PROB>|S|	0.0001
NUM ^= 0	54		
D:NORMAL	0.0880425	PROB>D	>0.15

QUANTILES(DEF=4)

100% MAX	1.3133	99%	1.3133
75% Q3	0.9565	95%	1.20997
50% MED	0.87	90%	1.1117
25% Q1	0.740025	10%	0.62
0% MIN	0.37	5%	0.42
		1%	0.37
RANGE	0.9433		
Q3-Q1	0.216475		
MODE	0.87		

MON=103H

UNIVARIATE

VARIABLE=LXBAR

MOMENTS

N	54	SUM WGTS	54
MEAN	-0.182323	SUM	-9.84544
STD DEV	0.252576	VARIANCE	0.0637945
SKEWNESS	-1.14209	KURTOSIS	2.27079
USS	5.17616	CSS	3.38111
CV	-138.532	STD MEAN	0.0343712
T:MEAN=0	-5.30453	PROB>|T|	0.0001
SGN RANK	-554.5	PROB>|S|	0.0001
NUM ^= 0	54		
D:NORMAL	0.12845	PROB>D	0.024

QUANTILES(DEF=4)

100% MAX	0.272543	99%	0.272543
75% Q3	-0.0445075	95%	0.18989
50% MED	-0.139262	90%	0.10588
25% Q1	-0.301195	10%	-0.478399
0% MIN	-0.994252	5%	-0.867501
		1%	-0.994252
RANGE	1.2668		
Q3-Q1	0.256687		
MODE	-0.139262		

NOTE: SAS INSTITUTE, SAS CIRCLE, BOX 8000, CARY, N.C. 27511-8000

TABLE A-9. AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTIONS FOR ROOF MONITOR 101G

ALUMAX DATA FOR ROOF MONITOR 101-G.

PLOT OF XBAR
NUMBER OF CASES = 56
MEAN OF SERIES = 0.760
STANDARD DEVIATION OF SERIES = 0.145

PLOT OF AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	.333	.134	(|*****)***
2	.132	.148	(|****)
3	.077	.150	(|**)
4	-.107	.150	(|***)
5	-.080	.152	(|***)
6	-.144	.153	(|****)
7	-.231	.155	(|******)
8	-.183	.161	(|*****)
9	-.075	.165	(|**)
10	.079	.165	(|**)
11	-.014	.166	(*|)
12	.101	.166	(|***)
13	.023	.167	(|*)
14	.096	.167	(|***)
15	-.014	.168	(*|)

PLOT OF XBAR
NUMBER OF CASES = 56
MEAN OF SERIES = 0.760
STANDARD DEVIATION OF SERIES = 0.145

PLOT OF PARTIAL AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	.333	.134	(|*****)***
2	.024	.134	(|*)
3	.029	.134	(|*)
4	-.161	.134	(*****|)
5	-.004	.134	(*|)
6	-.115	.134	(***|)
7	-.150	.134	(****|)
8	-.078	.134	(**|)
9	.034	.134	(|*)
10	.124	.134	(|****)
11	-.125	.134	(****|)
12	.101	.134	(|***)
13	-.102	.134	(***|)
14	.122	.134	(|****)
15	-.186	.134	(*****|)

TABLE A-10. AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTIONS FOR ROOF MONITOR 101H.

ALUMAX DATA FOR ROOF MONITOR 101-H.

XBAR COPIED FROM SYSTAT FILE INTO ACTIVE WORK AREA

PLOT OF XBAR
NUMBER OF CASES = 56
MEAN OF SERIES = 0.870
STANDARD DEVIATION OF SERIES = 0.131

PLOT OF AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	-.161	.134	(*****¦)
2	.063	.137	(¦**)
3	-.232	.138	(*****¦)
4	.068	.144	(¦**)
5	-.005	.145	(*¦)
6	-.136	.145	(****¦)
7	-.001	.147	(*¦)
8	.021	.147	(¦*)
9	-.053	.147	(**¦)
10	.006	.148	(¦*)
11	-.051	.148	(**¦)
12	.064	.148	(¦**)
13	-.113	.148	(***¦)
14	-.018	.150	(*¦)
15	.179	.150	(¦*****)

>PACF XBAR
PLOT OF XBAR
NUMBER OF CASES = 56
MEAN OF SERIES = 0.870
STANDARD DEVIATION OF SERIES = 0.131

PLOT OF PARTIAL AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	-.161	.134	(*****¦)
2	.038	.134	(¦*)
3	-.222	.134	(*****¦)
4	-.002	.134	(*¦)
5	.021	.134	(¦*)
6	-.201	.134	(*****¦)
7	-.037	.134	(*¦)
8	.030	.134	(¦*)
9	-.144	.134	(****¦)
10	-.020	.134	(*¦)
11	-.039	.134	(*¦)
12	-.035	.134	(*¦)
13	-.122	.134	(****¦)
14	-.082	.134	(***¦)
15	.173	.134	(¦*****)

TABLE A-11. AUTOCORRELATION FUNCTION AND PARTIAL AUTOCORRELATION FUNCTION FOR ROOF MONITOR 103G.

ALUMAX DATA FOR ROOF MONITOR 103-G.

XBAR COPIED FROM SYSTAT FILE INTO ACTIVE WORK AREA

PLOT OF XBAR
NUMBER OF CASES = 54
MEAN OF SERIES = 0.739
STANDARD DEVIATION OF SERIES = 0.208

PLOT OF AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
			+----+----+----+----+----+----+----+----+----+----+
1	-.119	.136	(***:)
2	.018	.138	(:*)
3	-.065	.138	(**:)
4	-.076	.139	(**:)
5	.029	.139	(:*)
6	.032	.139	(:*)
7	-.172	.140	(*****:)
8	.082	.143	(:***)
9	-.002	.144	(*:)
10	.035	.144	(:*)
11	-.128	.145	(****:)
12	.097	.147	(:***)
13	.129	.148	(:****)
14	.128	.150	(:****)
15	-.156	.152	(****:)

PLOT OF XBAR
NUMBER OF CASES = 54
MEAN OF SERIES = 0.739
STANDARD DEVIATION OF SERIES = 0.208

PLOT OF PARTIAL AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
			+----+----+----+----+----+----+----+----+----+----+
1	-.119	.136	(***:)
2	.003	.136	(:*)
3	-.063	.136	(**:)
4	-.093	.136	(***:)
5	.010	.136	(:*)
6	.034	.136	(:*)
7	-.181	.136	(*****:)
8	.038	.136	(:*)
9	.024	.136	(:*)
10	.014	.136	(:*)
11	-.154	.136	(****:)
12	.095	.136	(:***)
13	.180	.136	(:*****)
14	.118	.136	(:***)
15	-.151	.136	(****:)

TABLE A-12. AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTION FOR ROOF MONITOR 103H.

ALUMAX DATA FOR ROOF MONITOR 103-H.

XBAR COPIED FROM SYSTAT FILE INTO ACTIVE WORK AREA

PLOT OF XBAR
NUMBER OF CASES = 54
MEAN OF SERIES = 0.858
STANDARD DEVIATION OF SERIES = 0.193

PLOT OF AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	.282	.136	(|*****)**
2	.129	.146	(|****)
3	.038	.149	(|*)
4	-.049	.149	(**|)
5	-.387	.149	***(******|)
6	-.198	.167	(*****|)
7	-.081	.171	(***|)
8	-.024	.172	(*|)
9	-.021	.172	(*|)
10	.125	.172	(|****)
11	.130	.173	(|****)
12	.163	.175	(|*****)
13	.182	.178	(|*****)
14	.251	.181	(|*******)
15	.019	.188	(|*)

PLOT OF XBAR
NUMBER OF CASES = 54
MEAN OF SERIES = 0.858
STANDARD DEVIATION OF SERIES = 0.193

PLOT OF PARTIAL AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	.282	.136	(|*****)**
2	.054	.136	(|**)
3	-.013	.136	(*|)
4	-.069	.136	(**|)
5	-.391	.136	****(*****|)
6	.003	.136	(|*)
7	.054	.136	(|**)
8	.033	.136	(|*)
9	-.028	.136	(*|)
10	-.017	.136	(*|)
11	.039	.136	(|*)
12	.136	.136	(|****)
13	.149	.136	(|****)
14	.186	.136	(|*****)
15	-.103	.136	(***|)

TABLE A-13. AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTION FOR THE STANDARD DEVIATION OF MONTHLY MEANS FOR ROOF MONITOR 101G.

ALUMAX DATA FOR ROOF MONITOR 101-G.

THE VARIABLE IS THE STANDARD DEVIATION OF THE MONTHLY READINGS.

SX COPIED FROM SYSTAT FILE INTO ACTIVE WORK AREA

PLOT OF SX
NUMBER OF CASES = 56
MEAN OF SERIES = 0.133
STANDARD DEVIATION OF SERIES = 0.073

PLOT OF AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	-.061	.134	(**:)
2	-.171	.134	(*****:)
3	-.115	.138	(***:)
4	.003	.140	(:*)
5	-.189	.140	(*****:)
6	.101	.144	(:***)
7	-.044	.145	(**:)
8	.101	.146	(:***)
9	.061	.147	(:**)
10	.057	.147	(:**)
11	-.079	.148	(**:)
12	-.182	.149	(*****:)
13	-.210	.152	(******:)
14	.207	.158	(:******)
15	.034	.162	(:*)

PLOT OF SX
NUMBER OF CASES = 56
MEAN OF SERIES = 0.133
STANDARD DEVIATION OF SERIES = 0.073

PLOT OF PARTIAL AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	-.061	.134	(**:)
2	-.175	.134	(*****:)
3	-.143	.134	(****:)
4	-.052	.134	(**:)
5	-.254	.134	*(*****:)
6	.031	.134	(:*)
7	-.142	.134	(****:)
8	.054	.134	(:**)
9	.052	.134	(:**)
10	.044	.134	(:**)
11	.015	.134	(:*)
12	-.208	.134	(*****:)
13	-.233	.134	(*****:)
14	.087	.134	(:***)
15	-.082	.134	(***:)

TABLE A-14. AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTION FOR THE STANDARD DEVIATION OF MONTHLY MEANS FOR ROOF MONITOR 101H.

ALUMAX DATA FOR ROOF MONITOR 101-H.

PLOT OF SX
NUMBER OF CASES = 56
MEAN OF SERIES = 0.165
STANDARD DEVIATION OF SERIES = 0.082

PLOT OF AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	.010	.134	(| *)
2	.183	.134	(| *****)
3	.118	.138	(| ***)
4	.142	.140	(| ****)
5	-.046	.142	(** |)
6	-.043	.143	(** |)
7	-.093	.143	(*** |)
8	.111	.144	(| ***)
9	-.003	.145	(* |)
10	.129	.145	(| ****)
11	.057	.148	(| **)
12	-.003	.148	(|)
13	.150	.148	(| ****)
14	-.146	.151	(**** |)
15	-.070	.153	(** |)

PLOT OF SX
NUMBER OF CASES = 56
MEAN OF SERIES = 0.165
STANDARD DEVIATION OF SERIES = 0.082

PLOT OF PARTIAL AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	.010	.134	(| *)
2	.183	.134	(| *****)
3	.119	.134	(| ***)
4	.114	.134	(| ***)
5	-.090	.134	(*** |)
6	-.111	.134	(*** |)
7	-.114	.134	(*** |)
8	.145	.134	(| ****)
9	.089	.134	(| ***)
10	.151	.134	(| ****)
11	.038	.134	(| *)
12	-.135	.134	(**** |)
13	.075	.134	(| **)
14	-.188	.134	(***** |)
15	-.077	.134	(** |)

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TABLE A-15. AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTION FOR THE STANDARD DEVIATION OF MONTHLY MEANS FOR ROOF MONITOR 103G.

```
                    KLUMAX DATA FOR ROOF MONITOR 103-G.

SX IS THE STANDARD DEVIATION OF THE DAILY READINGS EACH MONTH.

       SX COPIED FROM SYSTAT FILE INTO ACTIVE WORK AREA

PLOT OF       SX
NUMBER OF CASES =  54
MEAN OF SERIES =       0.121
STANDARD DEVIATION OF SERIES =       0.086

PLOT OF AUTOCORRELATIONS

LAG   CORR     SE  -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
                   +----+----+----+----+----+----+----+----+----+----+----+
  1  -.221   .136                        (*****|      )
  2  -.076   .143                        (    **|      )
  3  -.229   .143                        (******|      )
  4   .267   .150                        (      |******)
  5  -.163   .158                        ( *****|      )
  6   .110   .162                        (      |***   )
  7  -.073   .163                        (    **|      )
  8   .196   .164                        (      |*****  )
  9  -.040   .168                        (     *|      )
 10   .115   .168                        (      |***   )
 11  -.125   .169                        (   ****|      )
 12  -.008   .171                        (     *|      )
 13  -.079   .171                        (    **|      )
 14   .178   .172                        (      |*****  )
 15   .015   .175                        (      |*      )

PLOT OF       SX
NUMBER OF CASES =  54
MEAN OF SERIES =       0.121
STANDARD DEVIATION OF SERIES =       0.086

PLOT OF PARTIAL AUTOCORRELATIONS

LAG   CORR     SE  -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
                   +----+----+----+----+----+----+----+----+----+----+----+
  1  -.221   .136                        (*****|      )
  2  -.132   .136                        ( ****|      )
  3  -.296   .136                      **(*****|      )
  4   .140   .136                        (     |****  )
  5  -.151   .136                        ( ****|      )
  6   .049   .136                        (     |**    )
  7   .016   .136                        (     |*     )
  8   .128   .136                        (     |****  )
  9   .136   .136                        (     |****  )
 10   .163   .136                        (     |***** )
 11   .059   .136                        (     |**    )
 12  -.036   .136                        (    *|      )
 13  -.054   .136                        (   **|      )
 14   .065   .136                        (     |**    )
 15   .073   .136                        (     |**    )
```

TABLE A-16. AUTOCORRELATION AND PARTIAL AUTOCORRELATION OF FUNCTION FOR THE STANDARD DEVIATION OF MONTHLY MEANS FOR ROOF MONITOR 103H.

ALUMAX DATA FOR ROOF MONITOR 103-H.

SX IS THE STANDARD DEVIATION OF THE DAILY READINGS EACH MONTH.

SX COPIED FROM SYSTAT FILE INTO ACTIVE WORK AREA

PLOT OF SX
NUMBER OF CASES = 54
MEAN OF SERIES = 0.155
STANDARD DEVIATION OF SERIES = 0.082

PLOT OF AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	.085	.136	(|***)
2	-.028	.137	(*|)
3	-.117	.137	(***|)
4	.006	.139	(|*)
5	-.063	.139	(**|)
6	-.142	.140	(****|)
7	-.012	.142	(*|)
8	-.037	.142	(*|)
9	.014	.142	(|*)
10	-.085	.142	(***|)
11	-.151	.143	(****|)
12	-.070	.146	(**|)
13	.208	.147	(|******)
14	.092	.152	(|***)
15	.124	.153	(|****)

PLOT OF SX
NUMBER OF CASES = 54
MEAN OF SERIES = 0.155
STANDARD DEVIATION OF SERIES = 0.082

PLOT OF PARTIAL AUTOCORRELATIONS

LAG	CORR	SE	-1.0 -.8 -.6 -.4 -.2 .0 .2 .4 .6 .8 1.0
1	.085	.136	(|***)
2	-.036	.136	(*|)
3	-.112	.136	(***|)
4	.025	.136	(|*)
5	-.074	.136	(**|)
6	-.146	.136	(****|)
7	.013	.136	(|*)
8	-.064	.136	(**|)
9	-.013	.136	(*|)
10	-.092	.136	(***|)
11	-.180	.136	(*****|)
12	-.080	.136	(***|)
13	.190	.136	(|*****)
14	.005	.136	(|*)
15	.113	.136	(|***)

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TABLE A-17. STATISTICS FOR DAILY ROOF MONITOR READINGS.

TOTAL OBSERVATIONS: 655

	X
N OF CASES	655
MINIMUM	0.24000
MAXIMUM	1.67000
RANGE	1.43000
MEAN	0.30860
STANDARD DEV	0.22068
SKEWNESS	0.34915
KURTOSIS	0.34027

TABLE A-18. STATISTICS FOR DAILY READINGS BY ROOM MONITORS.

THE FOLLOWING RESULTS ARE FOR:
RM# = 101G

TOTAL OBSERVATIONS: 168

	X
N OF CASES	168
MINIMUM	0.33600
MAXIMUM	1.31000
RANGE	0.97400
MEAN	0.76042
STANDARD DEV	0.19158
SKEWNESS	0.30920
KURTOSIS	-0.03543

THE FOLLOWING RESULTS ARE FOR:
RM# = 101H

TOTAL OBSERVATIONS: 168

	X
N OF CASES	168
MINIMUM	0.42000
MAXIMUM	1.65600
RANGE	1.23600
MEAN	0.87027
STANDARD DEV	0.19946
SKEWNESS	0.41516
KURTOSIS	0.60178

THE FOLLOWING RESULTS ARE FOR:
RM# = 103G

TOTAL OBSERVATIONS: 160

	X
N OF CASES	160
MINIMUM	0.28000
MAXIMUM	1.40000
RANGE	1.12000
MEAN	0.74748
STANDARD DEV	0.22181
SKEWNESS	0.33714
KURTOSIS	-0.11291

THE FOLLOWING RESULTS ARE FOR:
RM# = 103H

TOTAL OBSERVATIONS: 159

	X
N OF CASES	159
MINIMUM	0.24000
MAXIMUM	1.67000
RANGE	1.43000
MEAN	0.85586
STANDARD DEV	0.24225
SKEWNESS	0.32794
KURTOSIS	0.43047

TABLE A-19. REGRESSION ON POTLINE 101 ROOF MONITORS AND DRY SCRUBBERS.

THIS IS A REGRESSION ON RM101G AND DS161W.

DEP VAR: XBAR N: 19 MULTIPLE R: .063 SQUARED MULTIPLE R: .[illegible]

ADJUSTED $R^2 = 1-(1-R^2)*(N-1)$ DF, WHERE N= 19, AND DF= 17: .000

VARIABLE	COEFFICIENT	STD. ERROR	STD. COEF.	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.[illegible]451	0.062442	0.000000	.	12.13	.000
DSXBAR	0.[illegible]935	0.330649	0.063743	1.00000	.22	.733

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.001974	1	0.001974	.078	.783
RESIDUAL	0.428128	17	0.025184		

THIS IS A REGRESSION ON RM101H AND DS161E.

DEP VAR: XBAR N: 19 MULTIPLE R: .039 SQUARED MULTIPLE R: .002

ADJUSTED $R^2 = 1-(1-R^2)*(N-1)/DF$, WHERE N= 19, AND DF= 17: .000

VARIABLE	COEFFICIENT	STD. ERROR	STD. COEF.	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.359235	0.092767	0.000000	.	9.23	.000
DSXBAR	0.293209	1.816236	0.039124	1.00000	.16	.871

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.000754	1	0.000754	.026	.874
RESIDUAL	0.491958	17	0.028939		

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TABLE A-20. REGRESSION ON POTLINE 103 ROOF MONITORS AND DRY SCRUBBERS.

THIS IS A REGRESSION ON RM103G AND DS162W.

DEP VAR: XBAR N: 17 MULTIPLE R: .047 SQUARED MULTIPLE R: .002

ADJUSTED R^2 = 1-(1-R^2)*(N-1)/DF, WHERE N= 17, AND DF= 15: .000

VARIABLE	COEFFICIENT	STD. ERROR	STD. COEF.	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.670103	0.079648	0.000000	.	8.51	.000
DSXBAR	0.192647	1.063121	0.046736	1.00000	.18	.859

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.000856	1	0.000856	.033	.859
RESIDUAL	0.391145	15	0.026076		

THIS IS A REGRESSION ON RM103H AND DS162E.

DEP VAR: XBAR N: 17 MULTIPLE R: .474 SQUARED MULTIPLE R: .224

ADJUSTED R^2 = 1-(1-R^2)*(N-1)/DF, WHERE N= 17, AND DF= 15: .173

VARIABLE	COEFFICIENT	STD. ERROR	STD. COEF.	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.733068	0.091986	0.000000	.	7.97	.000
DSXBAR	1.712671	0.822092	0.473722	1.00000	2.08	.055

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.120134	1	0.120134	4.340	.055
RESIDUAL	0.415171	15	0.027678		

TABLE A-21. COVARIANCE MATRIES FOR ROOF MONITORS AND DRY SCRUBBERS.

THIS IS THE CORRELATION MATRIX FOR RM101G-DS161W.

COVARIANCE MATRIX

	XBAR	DSXBAR
XBAR	0.023900	
DSXBAR	0.000675	0.004151

NUMBER OF OBSERVATIONS: 19

THIS IS THE CORRELATION MATRIX FOR RM101H-DS161W.

COVARIANCE MATRIX

	XBAR	DSXBAR
XBAR	0.027373	
DSXBAR	0.000143	0.000487

NUMBER OF OBSERVATIONS: 19

THIS IS THE COVARIANCE MATRIX FOR RM103H-DS162W.

COVARIANCE MATRIX

	XBAR	DSXBAR
XBAR	0.033458	
DSXBAR	0.004384	0.002560

NUMBER OF OBSERVATIONS: 17

THIS IS THE COVARIANCE MATRIX FOR RM103G-DS161W.

COVARIANCE MATRIX

	XBAR	DSXBAR
XBAR	0.024500	
DSXBAR	0.000278	0.001442

NUMBER OF OBSERVATIONS: 17

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FIGURE A-1. PROBABILITY PLOT OF DAILY ROOF MONITOR READINGS.

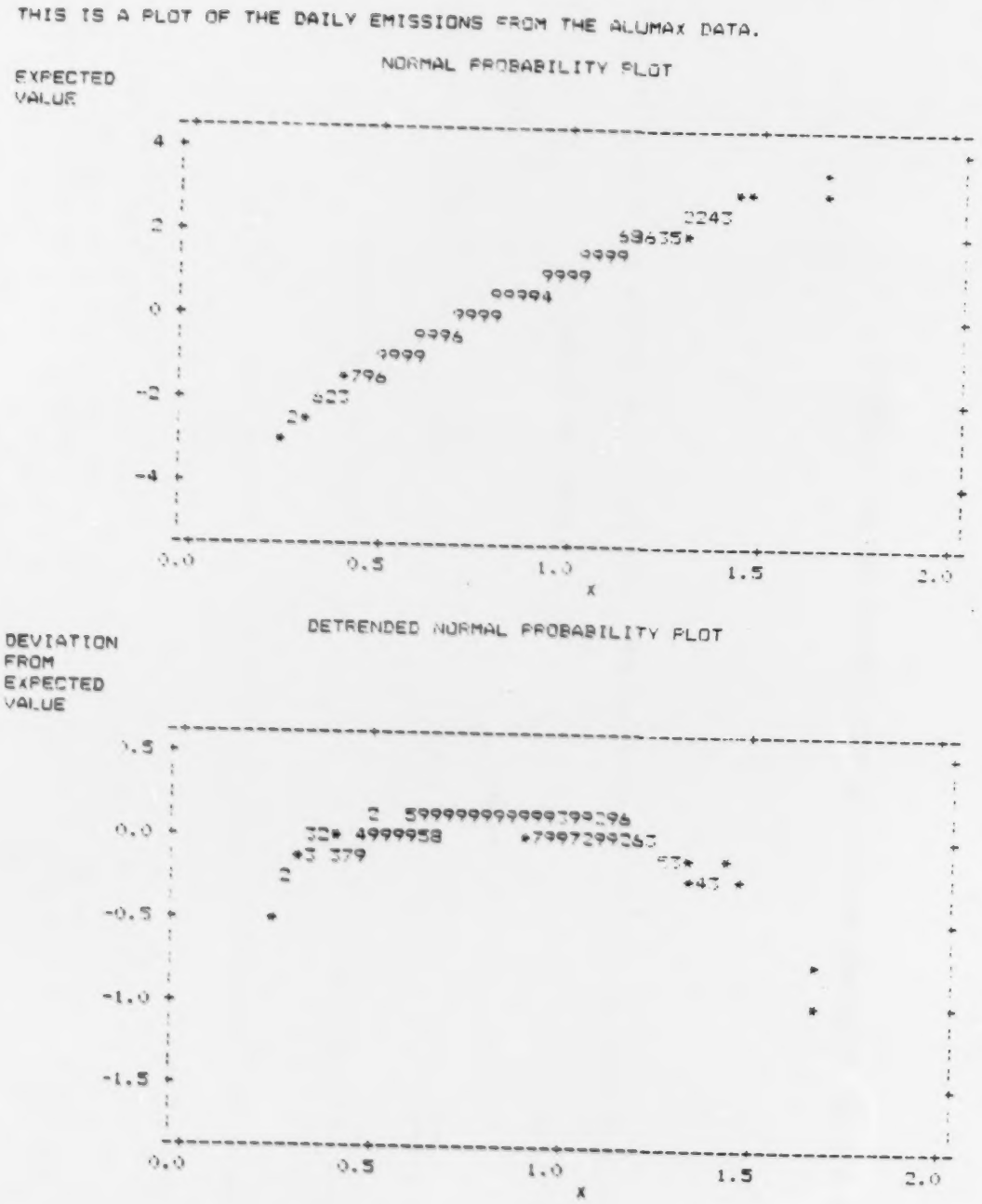
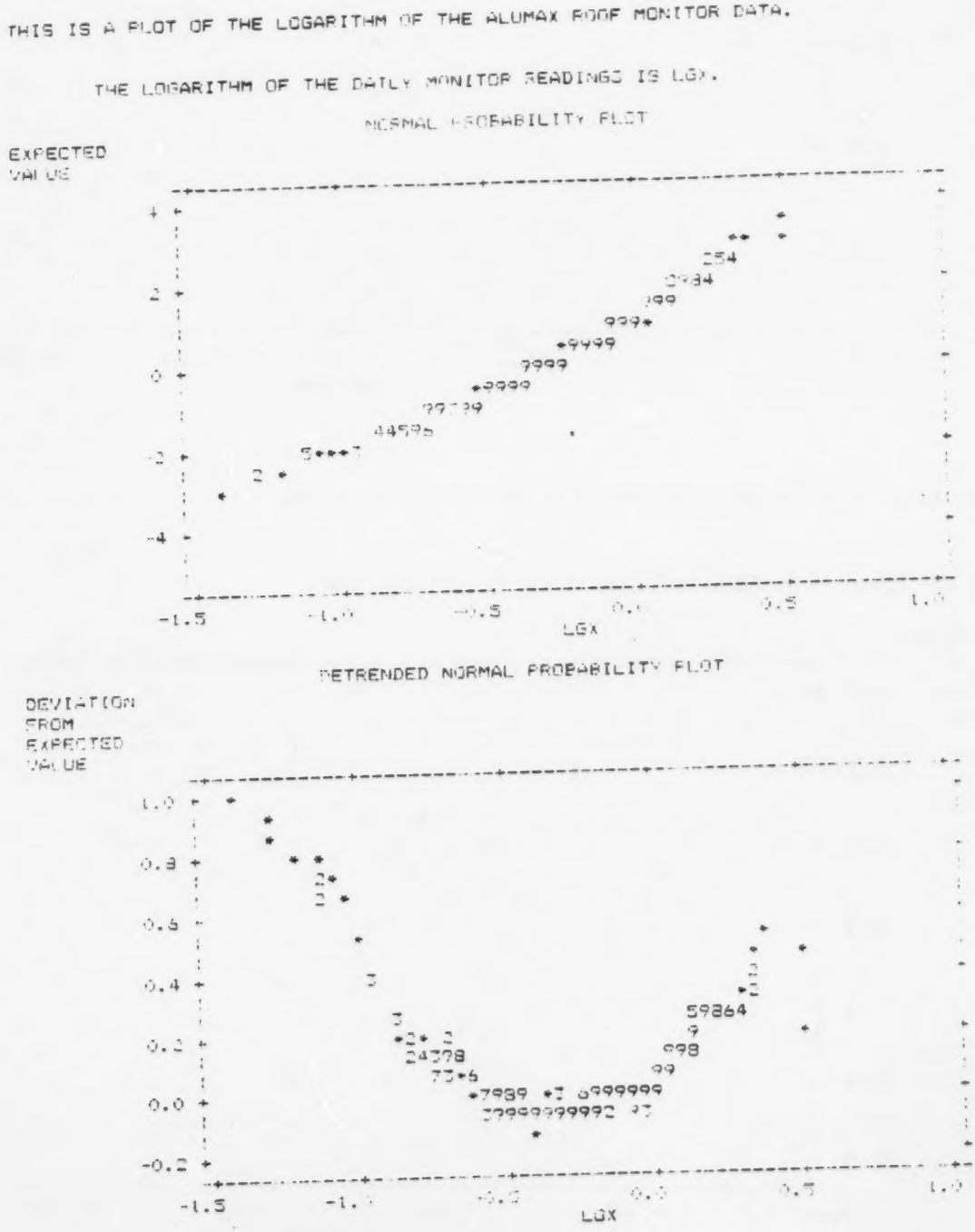


FIGURE A-2. PROBABILITY PLOT OF THE LOGARITHM OF THE DAILY ROOF MONITOR READINGS.



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FIGURE A-3a. PLOT OF RM 101G EMISSIONS VS. DS162W EMISSIONS.

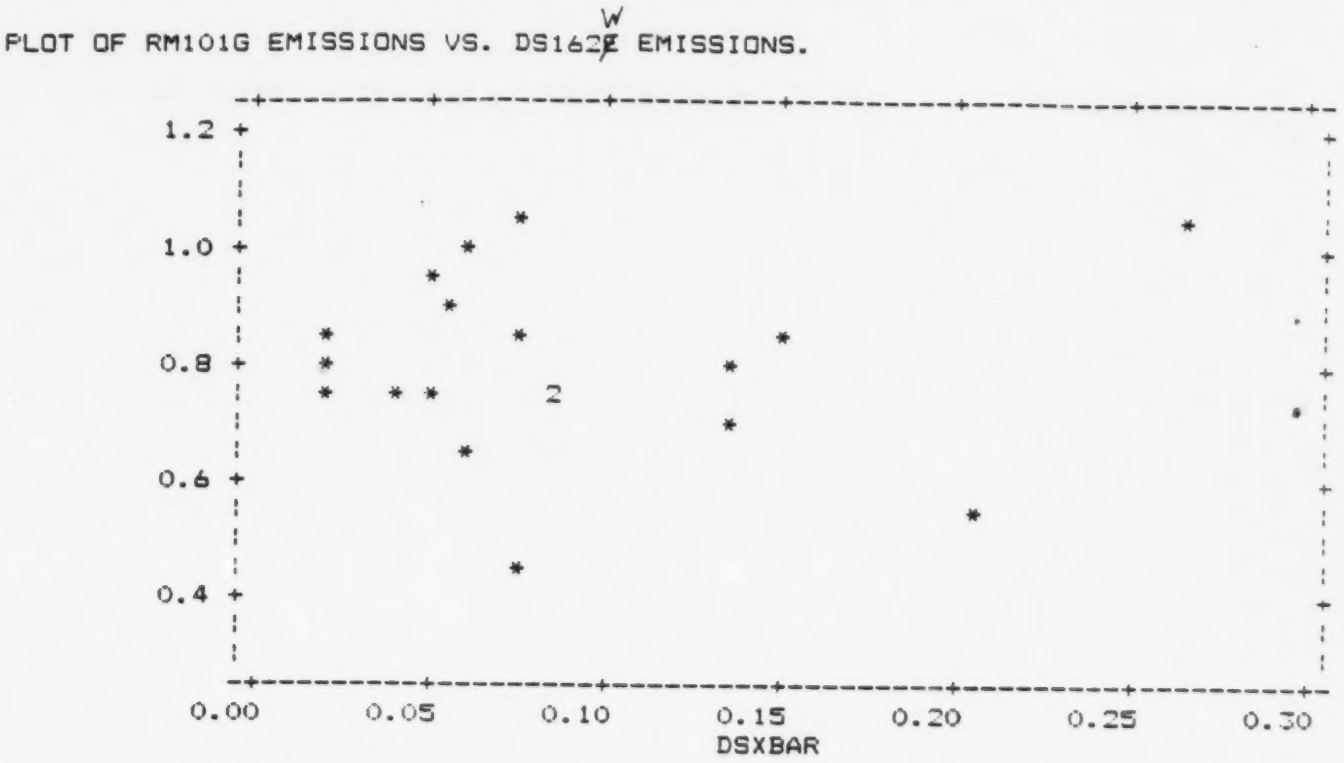


FIGURE A-3b PLOT OF RM 101H EMISSIONS VS DS161E EMISSIONS

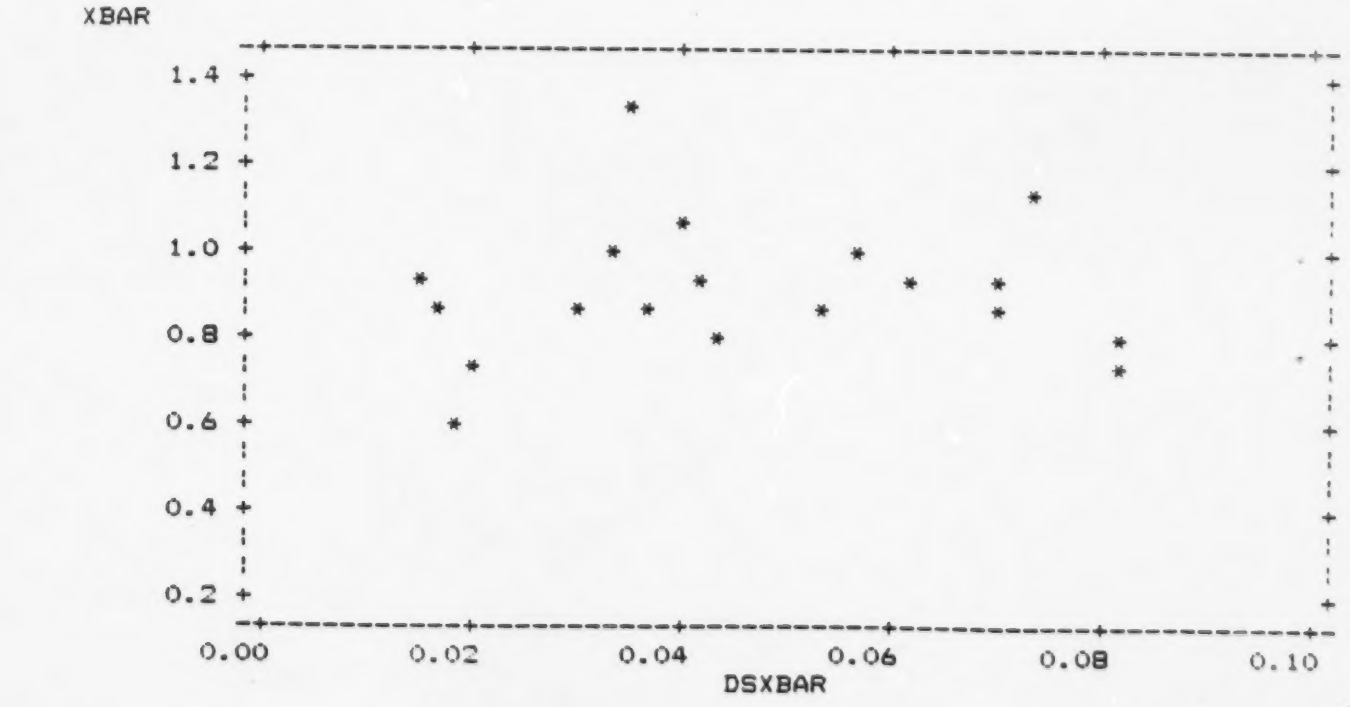


FIGURE A-4a. PLOT OF RM 103G EMISSIONS VS DS161W EMISSIONS.

PLOT OF RM103G EMISSIONS VS.DS161W.

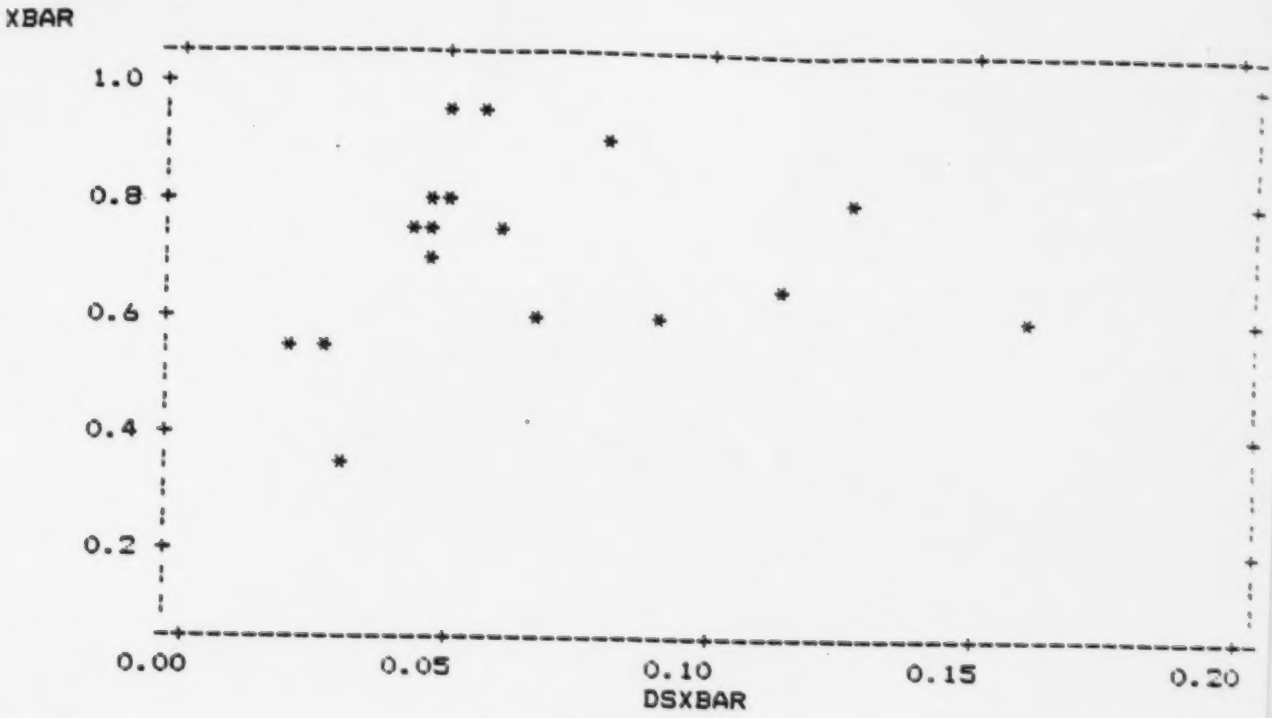
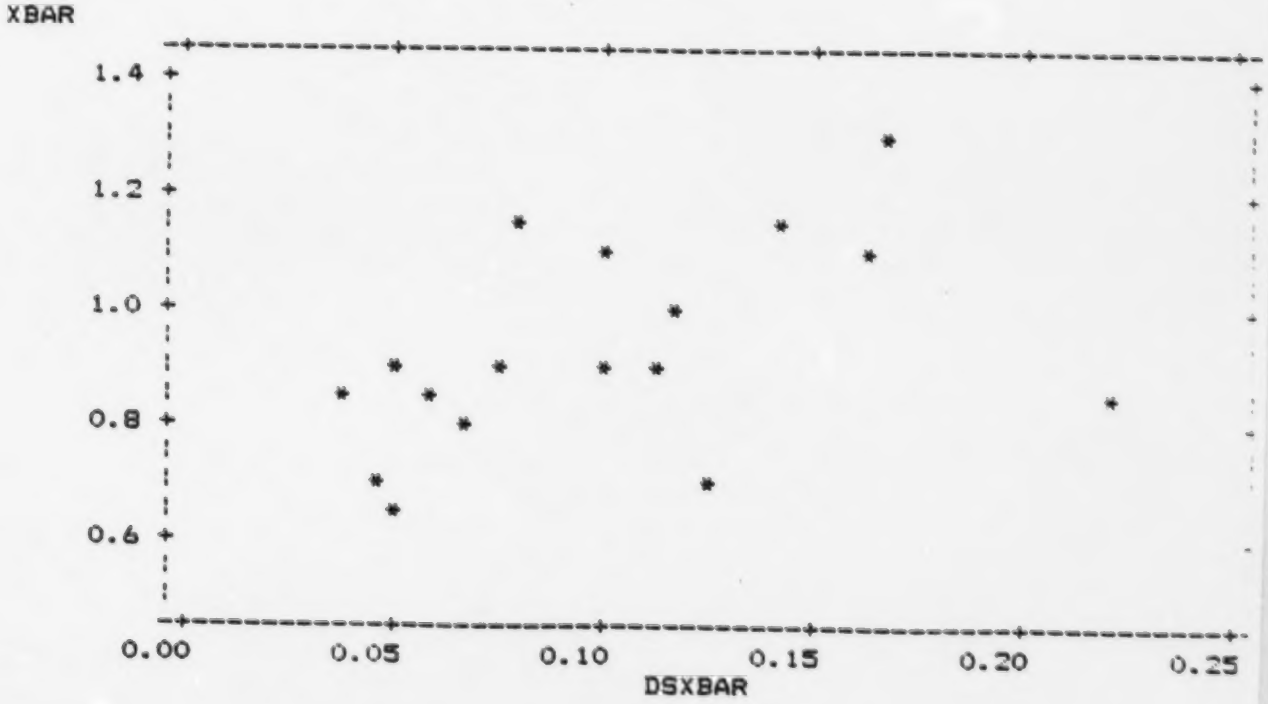


FIGURE A-4b PLOT OF RM 103H EMISSIONS VS DS162E EMISSIONS

PLOT OF RM103H EMISSIONS VS. DS 162E EMISSIONS.



APPENDIX B
CONTROL CHART PARAMETERS

Factors for computing control limits:[10]

All of the factors are functions of n only. Integer variable n is the number of samples that are taken per measurement. The constant 2 or 3 results from whether the 2-sigma limits or the 3-sigma limits are used. The 2-sigma limits are used with the upper and lower warning limits; the 3-sigma limits are used to calculate the upper and lower control limits.

$$C_4 = \sqrt{\frac{2}{n-1}}\,\frac{((n-2)/2)!}{((n-3)/2)!}$$

3-sigma limits

$A = 3/\sqrt{n}$

$A_3 = 3/(C_4\sqrt{n})$

$B_3 = 1-(3/C_4)(1-C_4^2)^{1/2}$

$B_4 = 1-(3/C_4)(1-C_4^2)^{1/2}$

$B_5 = C_4-3(1-C_4^2)^{1/2}$

$B_6 = C_4-3(1-C_4^2)^{1/2}$

2-sigma limits

$A_4 = 2/\sqrt{n}$

$A_5 = 2/(C_4\sqrt{n})$

$B_7 = 1-(2/C_4)(1-C_4^2)^{1/2}$

$B_8 = 1-(2/C_4)(1-C_4^2)^{1/2}$

$B_9 = C_4-2(1-C_4^2)^{1/2}$

$B_{10} = C_4-2(1-C_4^2)^{1/2}$

For n = 3

$$C_4 = (2/(3-1))^{1/2}\ ((3-2)/2)!/(0/2)!$$

$0! = 1.0$, $(-1/2)! = (\pi)^{1/2}$

$$C_4 = (1/2)\sqrt{\pi}/0! = 0.88623$$

TABLE B-1. CONTROL CHART FACTORS FOR SAMPLE SIZE OF THREE

3-sigma limits	2-sigma limits
$A = 3/\sqrt{3} = 1.732$	$A_4 = 2/\sqrt{3} = 1.1547$
$A_3 = 3/(C_4\sqrt{3}) = 1.954$	$A_5 = 2/(C_4\sqrt{3}) = 1.3029$
$B_3 = 0$	$B_7 = 0$
$B_4 = 2.568$	$B_8 = 2.045$
$B_5 = 0$	$B_9 = 0$
$B_6 = 2.276$	$B_{10} = 1.813$

Note that B_3, B_5, B_7, and B_9 calculate <0 by formulas given above, however B_3, B_5, B_7, and B_9 are always ≥ 0.

Calculations of Control Limits

Central Lines

For a potroom group the central lines of the $\bar{X}$ and s_x chart are calculated as follows:

(a) For samples of equal size

$$\bar{\bar{X}} = (\bar{X}_1 + \bar{X}_2 = \bar{X}_3 + \ldots + \bar{X}_k)/k \quad (1)$$

$$\bar{s}_x = (s_1 + s_2 + s_3 + \ldots + s_k)/k, \quad (2)$$

where $\bar{X}_i$ = the monthly mean potroom group emission for month i, lb F/T Al,

s_i = the monthly standard deviation of three daily readings, lb F/T Al.

k = the total number of months for which emissions data are available.

(b) For samples of unequal size the central lines are calculated as follows:

$$\bar{\bar{X}} = (n_1 \bar{x}_1 + n_2\bar{X}_2 + n_3\bar{X}_3 + \ldots + n_j\bar{X}_k)/(n_1+n_2 + \ldots + n_k), \quad (3)$$

$$\bar{s}_x = (n_1 s_1 + n_2 s_2 + \ldots + n_k s_k)/(n_1 + n_2 + n_3 + \ldots + n_k), \quad (4)$$

where n_i = the number of samples (daily readings) taken for month i.

Control Limits

(a) Upper and lower control limits - No Standard Given.

For $\bar{X}$ Chart

$UCL = \bar{\bar{X}} + A_3 \bar{s}_x$

$LCL = \bar{\bar{X}} - A_3 \bar{s}_x$

For S_x Chart

$UCL = B_4 \bar{s}_x$

$LCL = B_3 \bar{s}_x$

(b) Upper and lower control limits with respect to a given standard,

$\bar{X}_0$, σ_0 given

For $\bar{X}$ Chart

$UCL = \bar{X}_0 + A \sigma_0$

$LCL = \bar{X}_0 - A \sigma_0$

For s_x Chart

$UCL = B_6 \sigma_0$

$LCL = B_5 \sigma_0$

Warning Limits

(a) Upper and lower warning limits with respect to a given standard,

For $\bar{X}$ Chart

$UWL = \bar{X}_0 + A_5 \sigma_0$

$LWL = \bar{X}_0 - A_5 \sigma_0$

For $\bar{s}_x$ Chart

$UWL = B_{10} \sigma_0$

$LWL = B_9 \sigma_0$

Warning Limits Calculation

Central lines

$\bar{\bar{X}}$ Chart, $\bar{\bar{X}}_o$ = $\bar{\bar{X}}$ for potroom group

s_x Chart, σ_o = $\bar{s}_x$ for potroom group

Table B-2 gives the overall means, $\bar{\bar{X}}$, of the monthly mean emission rates for the ALUMAX potroom groups in lb F/T aluminum, and the mean of the monthly standard deviations, $\bar{s}_x$. For each potroom group the number of monthly observations, n, was three.

TABLE B-2. ALUMAX DATA FOR POTROOM GROUPS

Potroom Group	$\bar{\bar{X}}$	$\bar{s}_x$	n
101G/161W	0.8473	0.1499	3
101H/161E	0.9162	0.1663	3
103G/162W	0.8070	0.1265	3
103H/162E	0.9618	0.1651	3

Table B-3 shows the results of the calculation of upper and lower warning limits for the ALUMAX potroom groups. The warning limits were based on the constants for the 2-sigma control chart factors given in the equations above, and in Table 1. The upper and lower control limits were not calculated (with respect given standards, $\bar{\bar{X}}_o$ and σ_o because they will not be used for regulatory monitoring. The warning limits are to be used because their use would generally signal a process or maintenance procedure change before the upper and lower control limits would.

TABLE B-3. POTROOM GROUP WARNING LIMITS, ALUMAX DATA

Potroom Group	$\bar{X}$ Chart[a] Central Line, $\bar{X}_o$[b]	UWL	LWL	s_x Chart[a] Central Line, σ_o[c]	UWL	LWL
101G/161W	0.8473	1.043	0.652	0.1499	0.272	0
101H/161E	0.9162	1.133	0.700	0.1663	0.302	0
103G/162W	0.8070	0.972	0.642	0.1265	0.229	0
103H/162E	0.9618	1.177	0.747	0.1651	0.299	0

[a]Limits are based on a monthly sample size of 3, i.e., three daily readings per month to calculate $\bar{X}_i$ and s_x.

[b]Standard central line $\bar{X}_o = \bar{\bar{X}}$, overall mean of monthly means for ALUMAX data.

[c]Standard deviation $\sigma_o = \bar{s}_x$ for ALUMAX data.

APPENDIX C
HYPOTHESIS TESTING

In hypothesis testing the null hypothesis defines what test is being conducted. The hypothesis always relates to true values, or population values. The test statistic is a calculated value used to test the hypothesis. The test statistic uses sample parameters, as contrasted to population parameters.

For example, the true mean (of a population) is generally symbolized as μ, whereas the mean of a sample is symbolized as $\bar{X}$.

In the hypothesis test needed in the application used for this report, the hypothesis to be tested is:

$$H_o : \mu_1 > \mu_o,$$

where μ_o is the true mean value of the monthly mean emissions used to qualify a potroom group for a less frequent performance test schedule, and μ_1 is the true mean of a set of emission measurements (8 in the examples in this study) taken after the upper warning limits have been violated on the $\bar{X}$ control chart for a given potroom group. The judgement that needs to be made is whether the overall emissions level (the true population mean, μ_1) has increased from the original level μ_o.

In making a decision based on a hypothesis test, two types of mistakes are possible.

a. the decision can be made that the hypothesis is correct, when in fact it is not; and

b. the decision can be made that the hypothesis is incorrect, when in fact it is true.

The test is constructed to minimize the probability of making the second type error, at what is taken as , the level of significance. For most cases, is taken as 0.05, indicating a 5 percent probability of making an error of type b above. That is, there would be only a 5 percent error that the hypothesis is rejected when in fact it is correct. The hypothesis test is outlined below:

Hypothesis: $H_0 : \mu_1 > \mu_0$

Test Statistic:

$$t = (\bar{\bar{X}}_1 - \bar{\bar{X}}_0) / [s_p \sqrt{1/n_1 + 1/n_0}],$$

$$s_p = [((n_1 - 1)\, s_1^2 + (n_0 - 1)\, s^2_0) / (n_1 + n_0 - 2)]^{1/2},$$

$$\text{with } df = (n_1 + n_0 - 2)$$

Critical Values: $t_{df,0.95}$.

If $t > t_{df,0.95}$, then accept H_0, otherwise reject H_0. Critical value $t_{df,0.95}$ is Student's t statistic, one-tailed at the 0.05 level of significance with df degrees of freedom.

Example:

Table 5-3 gives the 56 values of $\bar{\bar{X}}_1$ (XBAR) on which $\bar{\bar{X}}_0$ is based for Potroom Group 101G/161W.

$$\bar{\bar{X}}_0 = \bar{\bar{X}} = 0.8473$$

$$S_{\bar{\bar{X}}} = S_0 = 0.1520$$

$$n_0 = 56$$

As given in Appendix D, UWL for the $\bar{\bar{X}}$ chart = 1.043. Suppose the following consecutive monthly mean performance tests were conducted:

$$\bar{\bar{X}}_1 = 1.0496$$

$$\bar{\bar{X}}_2 = 0.9224$$

$$\bar{\bar{X}}_3 = 0.8090$$

$$\bar{X}_4 = 0.8857$$

$$\bar{X}_5 = 1.0524$$

$$\bar{X}_6 = 0.8357$$

$$\bar{X}_7 = 1.0270$$

$$\bar{X}_8 = 0.9063$$

For the last 8 monthly mean emissions:

$\bar{\bar{X}}_1$ = the mean of $\bar{X}_1$, $\bar{X}_2$, $\bar{X}_3$, ..., $\bar{X}_8$, and

S_1 = the standard deviation

$n_1 = 8$

Therefore, $\bar{\bar{X}}_1 = 0.9360$

$S_1 = 0.0960$

$n_1 = 8$

The question, is "Has the true mean emission level from which the last 8 samples were taken changed from the original level where $\bar{X}_o = 0.8473$, $S_o = 0.1520$, and $n_o = 56$?"
Therefore, test the hypothesis:

$$H_o : \mu_1 > \mu_o$$

Test Statistic:

$$t = (0.9360 - 0.8473) / [s_p \sqrt{1/56 + 1/8}],$$

$$s_p = [((55(0.1520)^2 + 7(0.0960)^2) / (56 + 8-2)]^{1/2}$$

$$s_p = 0.14675$$

$$t = 1.5992$$

$$df = 62$$

$$t_{62,0.95} = 1.671$$

Because t is less than $t_{62,0.95}$, the null hypothesis, H_o must be rejected. That is to say, that there is not a significant difference between 0.9360 and 0.8473 at the 5 percent level of significance. The conclusion that must be reached is that from the data we have collected, we can not say that the overall mean has increased for the last 8 runs.

APPENDIX D

SUMMARY OF PRIMARY ALUMINUM PLANT PERFORMANCE

TABLE D-1. TOTAL FLUORIDE EMISSIONS FROM POTROOMS SUBJECT TO NSPS

Plant Code	Plant Type	Number Monthly Tests	Measured Emissions lb F/T Al			NSPS Limit lb F/T Al	Number of Exceedances	References
			Min.	Max.	Avg.			
A	CWPB[a]	51	0.55	1.30	0.89	1.9	0	16
B	CWPB	48	0.42	1.31	0.86	1.9	0	16
C	CWPB	34	0.67	3.48	1.27	1.9	3[c]	17,18
D	CWPB	16	0.71	1.49	1.04	1.9	0	19
E	VSS[b]	22	0.88	3.11	1.49	2.0	3[d]	20

[a]CWPB - Plant uses center-worked prebake pots.

[b]VSS - Plant uses vertical stud Soderbrg pots.

[c]Two failures occurred in same month, one on retest.

[d]Specific reason for failures not reported. Plant conducts one test run/line each month, so each reported test is the average for all three lines.